41st
AUDIO ENGINEERING SOCIETY
CONVENTION

WORKSHOP ON
STUDIO TAPE RECORDERS
Wednesday, October 6, 1971
9:00 AM-5:00 PM
Terrace Room, Hotel New Yorker
34th Street and Eighth Avenue

John Howell

AUDIO ENGINEERING SOCIETY WORKSHOP ON STUDIO TAPE RECORDERS

FORTY-FIRST CONVENTION

OCTOBER 6, 1971

The intent of this Workshop is to familiarize you with the basic design and functional developments that have been achieved in the professional recorder and to give you some practical ideas on how to evaluate the performance and to maintain the performance of these sophisticated devices.

We are going to look at the recorder as a system which will include the transport, the recording heads, the amplifiers and the tape. Because of the elements and their side effects in the system, it is important to make meaningful tests which will indicate the performance of these elements.

When making these tests be sure that the measurement made is the result of a cause and not an effect.

Too many times playback frequency response has been electrically compensated when in fact the problem was really dirt on the playback head.

The following pages of data, technical articles, excerpts from instruction manuals, charts and graphs are for your reference during this Workshop. They will form a permanent reference and guide for field alignment procedures and maintenance problems on studio-type tape recorders — from mono broadcast to multichannel recording.

This Workshop has been put together for the Audio Engineering Society by the New York Section Executive Committee with special assistance from the following people:

Bob Berliner	Carl Berntsen	Hamilton Brosious
Bob Burnett	Delos Eilers	Sidney Feldman
Arthur Gruber	C. Harned	Jacqueline Harvey
Thomas Haskett	Alastair Heaslett	Irving Joel
Ted Johnson	J. G. McKnight	Bill Morin
Frank Rush	Clifford Rogers	Dorothy H. Spronck
Henry Van der Wall	Bill Wilson	Bill Windsor
John Woram		

We are also grateful to the following companies for their donations of equipment and time to this Workshop:

Ampex Corporation	Crown International
MCI	Philips Broadcast Equipment
Scully Recording Instruments	3M, Mincom Division and Magnetic Products Division

Irving Joel, Executive Producer

VAR. Tape Thickness = Var-Speed.
20° Phase Shift OK = 0 & 1DB - using tracks 2 & 7

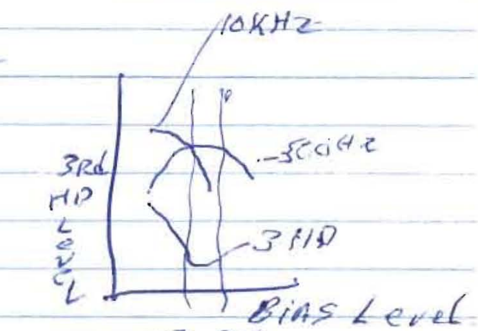
2nd & 3rd harmonic distortion - Need IM meter
Measurements should correlate to listening

Degauss - 2nd harmonic will indicate
A. Check 60 ~ degauss field strength

PP / Induced freq into head - Flux inducing loop - 500 Hz
needs equalizer if you want response flat = .3 mfd
Eliminates wave length effects.
Buy from Ampex

RE / Bias - Peak Bias setting usually 750 Hz

A. Use 10KHz - find peak and decrease it 2 dB to arrive at lowest part of 3rd HD curve.



B. Freq.
C. Dist.
only at 15"/sec at operating level

PARTS
MOTORS .05 ounce cap. = 5Kc

Heads

wear = increased reluctance = increased efficiency = Bias change

$$dB\ Loss = \frac{55\,d\ (\text{microinches})}{\lambda}$$

90° Phase Shift = -3dB
Most Heads 30° at 1K.

MAGNETIC RECORDING

Mincom Division

MINNESOTA MINING AND MANUFACTURING COMPANY
300 South Lewis Road, Camarillo, California 93010

3M COMPANY

will depend upon the direction of the current. The end of the broken ring from which the arrows emanate is called the north pole and the end of the ring where the arrows enter is called the south pole. These poles are reversed when the direction of the current is reversed.

Certain materials which are suitable for use as a magnetic ring or core permit the magnetic flux to vary proportionally to changes in the exciting current. Other materials may remain permanently magnetized after the current which causes the magnetism is turned off. In magnetic recording there are uses for each of these two types of materials.

THE RECORD HEAD. A magnetic tape recorder employs a device very similar to the ring structure previously described. In this device, which is called a record head, flux in an air gap varies directly with the current through its coil. The length of the gap in the record head is extremely small—in some cases less than one thousandth of an inch.

THE TAPE. A material that remains permanently magnetized is used in magnetic recording systems to record the flux variations in the record head gap. This material is usually a very thin layer of ferric oxide, coated on a mylar base tape. It is this metallic coating which receives and retains the magnetic image.

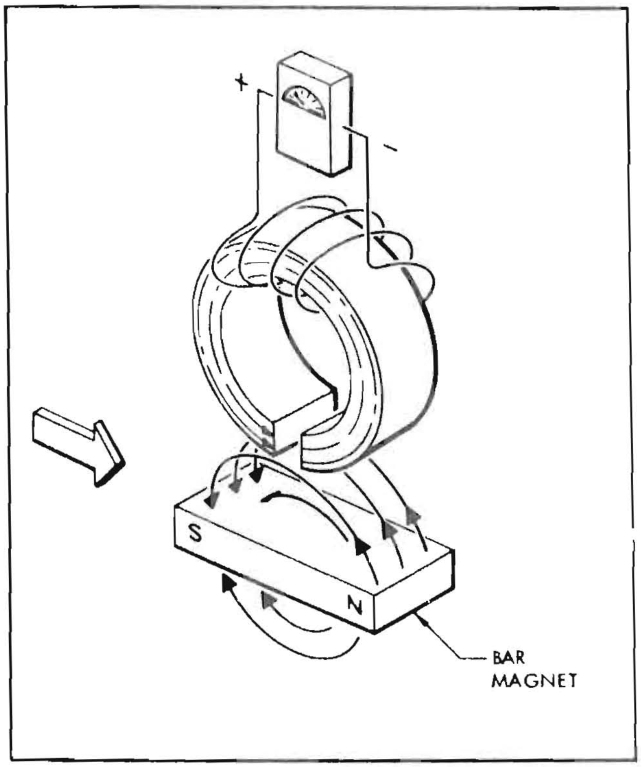


Figure 3. Reproduce Head

Tape is moved across the record head as shown in figure 2. It slides over the head in contact with the ring at the air gap. It is bowed slightly around the head to assure adequate contact at the gap. The tape lying beneath the gap is influenced by the flux in the gap. As illustrated in figure 2, each point of the tape experiences flux for a very short interval of time as it moves past the gap. In this manner, the tape retains along its length a magnetized impression of the current variations in the coil.

The process of creating a magnetic field with an electric current is reversible. Figure 3 shows a ring assembly, similar to the one previously described, with a sensitive ammeter connected across its coil. As a bar magnet is moved past the gap, the magnetic flux intercepted by the gap causes the meter needle to deflect to the right, indicating that an electric current is being produced. If the magnet were simply held close to the gap, but stationary, no current would be generated and the needle would stay in the center of the scale. If the magnet were moved past the gap in the same direction, but at an increased rate, the needle would deflect even further to the right. If, however, the magnet were moved past the gap in the opposite direction, the electric current would flow in the opposite direction from which it had been flowing, and the meter needle would deflect to the left. The magnitude of the current produced in the coil is proportional to the *rate of change* of magnetic flux experienced by the coil, and the direction of the current depends upon the direction in which the flux lines are flowing.

The magnetic impressions which have been recorded on the tape are sources of magnetic flux. Consequently, a varying electrical current similar to the one originally used to make a recording can be produced. To produce this current, the tape is passed over a ring similar to the record head, only with a current sensing device instead of a current source connected to its coil.

In principle, magnetic recordings are made and reproduced exactly as has been described. In a practical magnetic recorder, however, many refinements are necessary to insure that the reproduced signal is exactly like the one originally used to make the recording.

A BASIC RECORDER. Figure 4 illustrates a magnetic tape recorder in its simplest form. Sound entering the microphone is converted into an alternating electric current. This current flows through the coil of the record head and sets up on the tape alternatingly polarized, magnetized bits of information. Later, the tape passes the gap in the reproduce head and causes an alternating current to be generated in its coil. This current

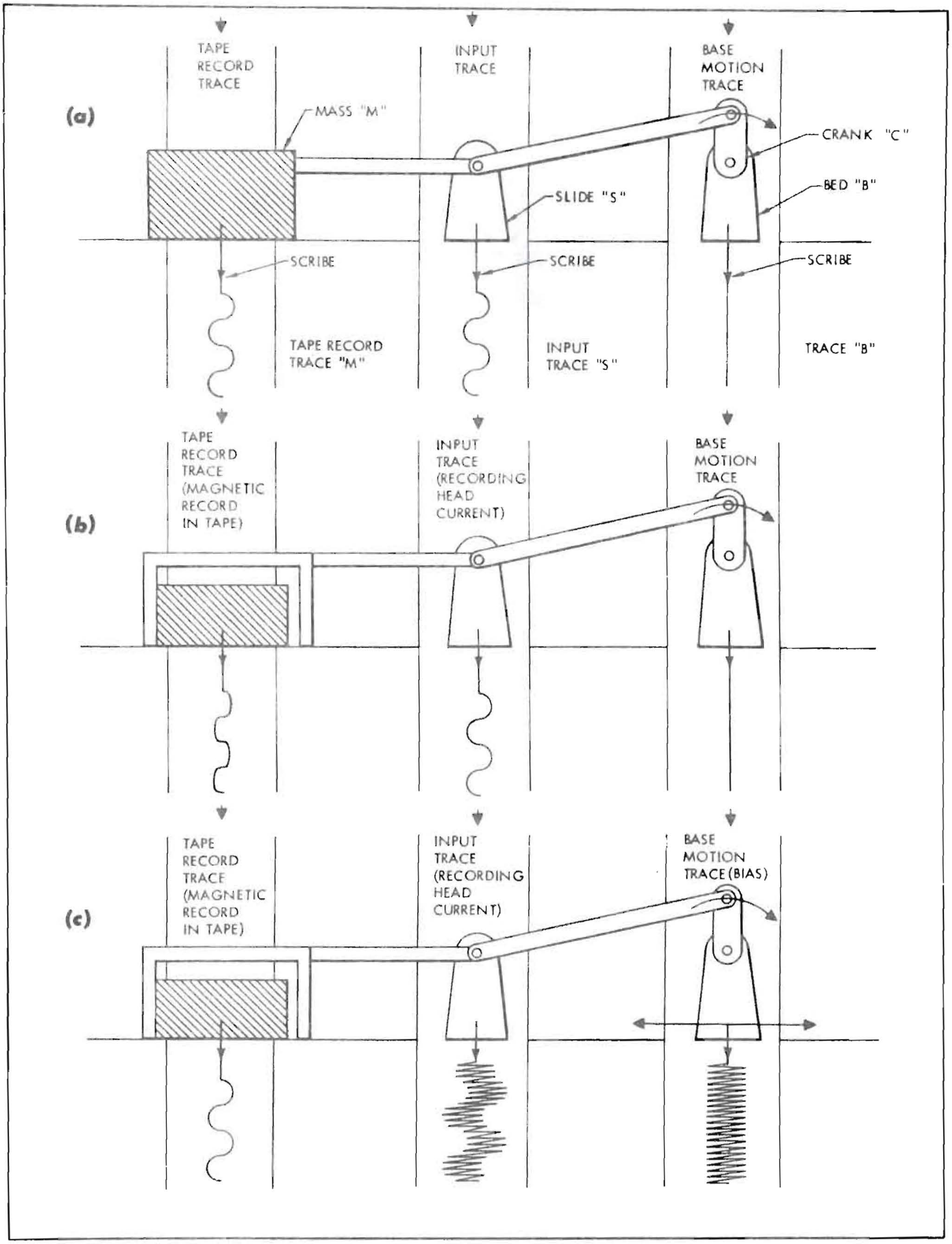


Figure 5. Mechanical Analogy

cycles) to be faithfully recorded. The only function of the bias frequency is to agitate the tape magnetically with sufficient force to take out the backlash. There is no intention of actually recording it on the tape.

AN ADVANCED RECORDER. Figure 6 shows the simple tape recorder of figure 4 after it has been modified by the addition of amplifiers and a source of high frequency bias. An amplifier "A1" has been added between the microphone and the record head. Both the output of this amplifier and the output of "B", a high frequency vacuum tube oscillator, are used to drive the record head. With this apparatus, it is possible to lay down along the tape a strong and faithful copy of the electrical currents which it is desirable to record. On playback, amplifier "A2" builds up the weak signals from the head sufficiently to make them operate a loudspeaker.

FURTHER REFINEMENTS—FREQUENCY RESPONSE DISTORTION. The device of figure 6 will give satisfactory results for some purposes, but the reproduction is lacking in smoothness of frequency response. Some frequencies in the audible range of 30 to 15,000 cycles per second are not reproduced as loudly as are others. Generally, extremely low and extremely high frequencies are more difficult to record and reproduce than those in between. This results in an attenuation at both ends of the spectrum which is noticeable to the ear. Figure 7 is a frequency response graph of the recorder/reproducer depicted in figure 6. The straight line "A" represents the intensity of sounds entering the microphone. The curved line "B" is a plot of the intensity with which various frequencies will be reproduced.

To make the reproduced sounds from this recorder similar to the original sounds, it is necessary to amplify different frequencies different amounts in accordance with a curve which is the opposite, or reciprocal, of curve "B". As indicated by curve "B", frequencies of about 10,000 cycles suffer such severe loss in intensity that they cannot be restored at all, and the correction for frequency response shown in curve "C", figure 7, can be carried only so far. A similar condition exists for extremely low frequencies, with the result that the over-all response of the corrected recorder/reproducer follows curve "D". While there is a rapid drop at the extremes, the most important part of the frequency spectrum is now reproduced with uniform response, closely matching the original curve "A". By means to be described later, frequency response can be extended as high as two megacycles or more.

CAUSES OF FREQUENCY DISCRIMINATION. Figure 8 shows a simple, but workable, recording circuit. Alternating voltages to be recorded are applied to the terminals marked "In-

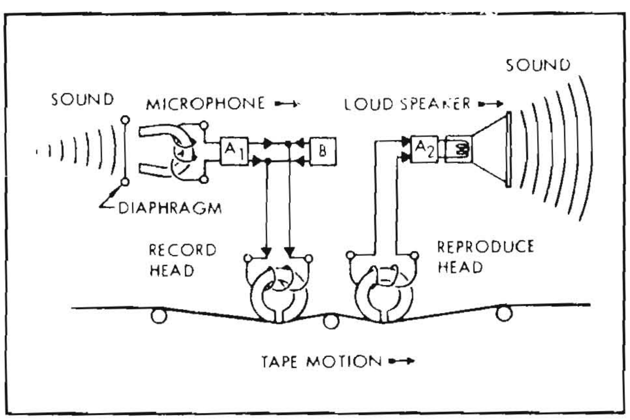


Figure 6. Advanced Recorder

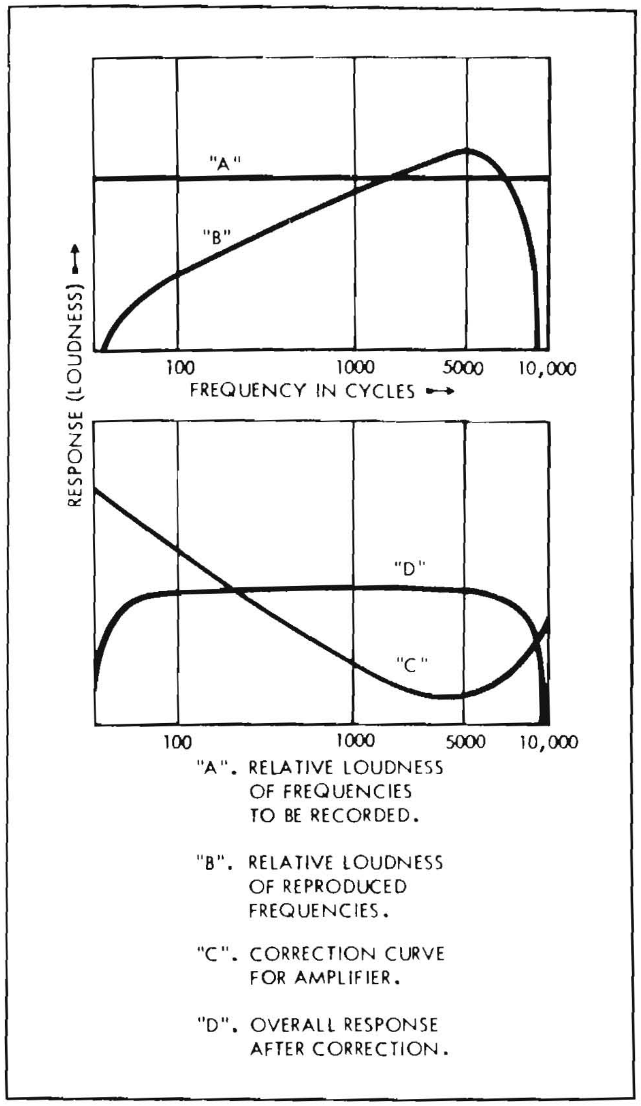


Figure 7. Frequency Response Graph

put". The current through the pentode vacuum tube varies directly in proportion to the input voltage. Since the record head is connected to the plate of the tube through a large capacitor, the current in the coil varies directly with the signal voltages to be recorded.

The pentode is used primarily to assure that the current in the record head follows the input voltage, regardless of frequency. Normally, if a source of constant voltage, but of variable frequency, is connected directly to a device like the record head, the current will decrease as the frequency increases. This is due to a choking effect caused by that property of a coil of wire known as its inductance. When the pentode is inserted between the input and the coil, the current through the coil becomes practically independent of frequency. The coil current, therefore, is determined only by the magnitude of the input voltage. If an alternating current of constant amplitude is used to drive a record head, a series of magnets is recorded in the tape as shown in figure 9. As the frequency increases, the magnets on the tape become shorter and shorter. Due to the constant current in the record head, however, the tape is uniformly magnetized, regardless of the length of any of its magnetic impressions. In other words, all magnets regardless of length are of equal strength because they are all generated by currents of equal magnitude.

When the tape passes the reproduce head, each of these magnets sets up an equal number of lines of flux in the head. The tape is moving along at a constant speed, so that a long magnet takes a greater time to pass the head than does a short one. Thus, longer magnets generate low frequencies and shorter magnets generate high frequencies. Since the current generated in the coil of the head is proportional to the *rate of flux change*, the long and short magnets do not produce currents of equal magnitude. The short magnets generate larger currents because they pass the gap more rapidly than the long ones. Consequently, the amplitude of the output signal is directly proportional to the frequency of the recorded signal. For example, the output signal at 3,200 cycles per second is 32 times as great as at 100 cycles per second. The effect of frequency on the output amplitude accounts for the long straight slope of curve "B" between 100 and 5,000 cycles.

CORRECTIVE EQUALIZATION.

SLOPE CORRECTION. This difficulty can be corrected in the reproduce amplifier by employing the network shown in figure 10a. A capacitor "C" acts as an open circuit, or infinitely high resistance to direct current, but as a resistor of finite value to alternating current. As the frequency of alternating current increases, the effective resistance (or impedance) of the capacitor decreases. With a constant voltage across the input terminals of figure 10a, the voltage across the output terminals drops as the frequency increases. Because "C" acts as a different size resistor for different frequencies, while "R" remains constant, the voltage is reduced in proportion to the radio between "R" and the effective resistance of "C". This device has a characteristic which is the opposite of that of the reproduce head and may be used to correct for the sloping portion of the response curve, line "B" in figure 7, lying between approximately 100 and 500 cycles.

CURVATURE CORRECTION. If another resistor is added to the network, as shown in figure 10b, then the voltage will no longer fall, but remain constant above a certain frequency. This helps correct for the curved portion of "B", figure 7, in the region of approximately 5,000

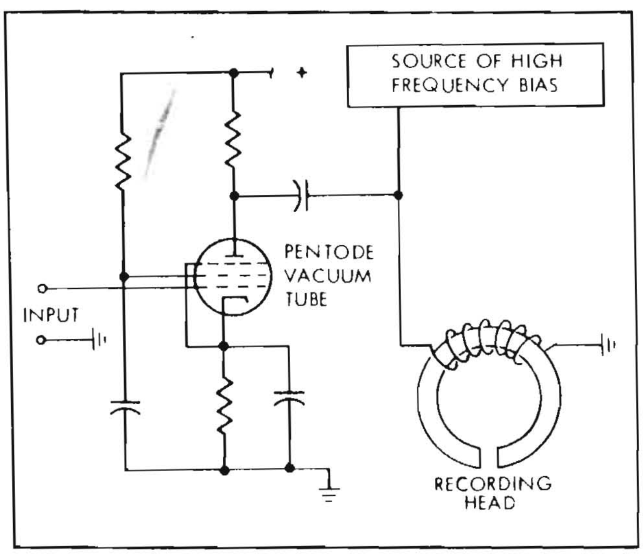


Figure 8. Simple Recording Circuit

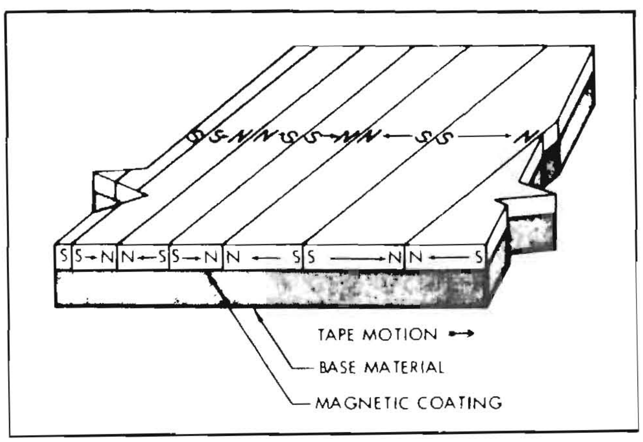


Figure 9. Tape Magnetization

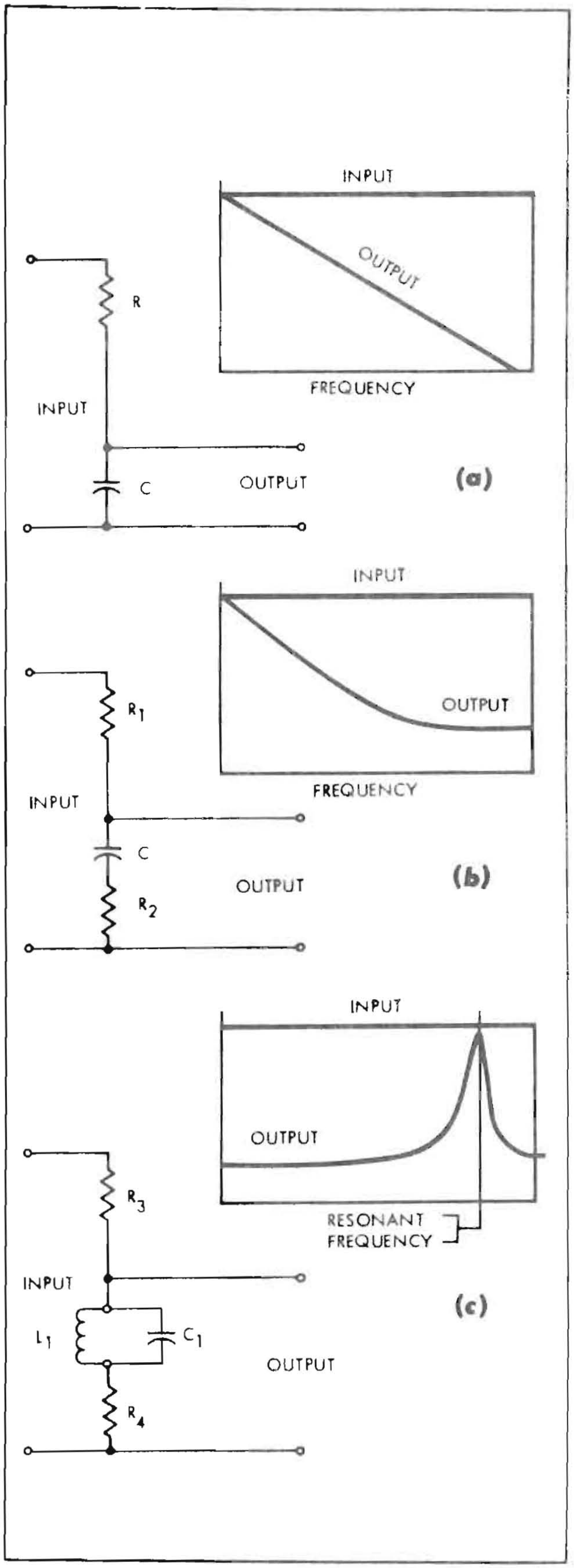


Figure 10. Corrective Networks

cycles. Above 5,000 cycles, however, the curve actually reverses direction. This often calls for another type of equalizer, one that causes the amplifier to have greater sensitivity at higher frequencies.

HIGH FREQUENCY LOSS CORRECTION. A high frequency loss correction network, together with its characteristic curve, is shown in figure 10c. At low frequencies, "L" acts as a very low resistance, and the output bears a relation to the input which is determined by the ratio of R3 to R4. The same is true at very high frequencies where "C" acts as a very low resistance. However, at some intermediate frequency, known as the resonant frequency, "L" reacts with "C" so that, in effect, their resistance is extremely high. For this reason, the output rises very sharply near resonance and is highest at the resonant frequency.

OVER-ALL CORRECTION. A network of this sort, used in conjunction with the network of figure 10b, will result in very effective correction for the rapid decay above 5,000 cycles in curve "B" of figure 7. By utilizing these networks, the corrective curve "C" in figure 7 can be readily made to match the loss curve "B". The over-all result will then approach that of curve "D". Since these corrective networks all cause losses, additional stages of amplification must be provided in the reproduce amplifiers.

GAP LENGTH LOSSES. Paragraph gave the explanation for the long straight slope of curve "B", figure 6, between 100 and 5,000 cycles. The reverse slope above 5,000 cycles is explained below.

Figure 11 shows the magnetized surface of a tape passing under a reproduce head. Six different positions of the tape in contact with the head are shown. The head is connected directly to a sensitive voltmeter. No equalization is included between the head and the voltmeter. The tape is considered to be moving past the head at a constant velocity.

In position 1, a long magnet is being scanned. The resulting low frequency produces a very low voltage. In 2, the magnets are somewhat shorter, and a higher voltage is generated because the frequency is higher. Similarly, in 3 and 4 the frequency and voltage are still higher. In fact, the magnet length in 4 is equal to the gap length of the head.

A higher output voltage cannot be obtained than that of case 4 because, as the magnets get shorter than the gap length, a condition like that at 5 is found. Here, one magnet lies well within the gap, but the adjacent magnet, of opposite

polarity, also lies partly within the gap. The adjacent magnet's effect is to partially cancel the effectiveness of the first magnet. Therefore, the flux lines in the reproduce head cannot possibly be as dense as in 4, and the output voltage is reduced. In case 6 the magnets are still shorter, exactly two magnets being within the gap. Their net effect on the reproduce head is to generate no voltage whatever. This rapid drop in the voltage from maximum at 4 to zero at 6 occurs when the magnet length on the tape is cut in half. That is, in 4 one magnet fills the gap, and in 6 the magnets are just half as long. Therefore, we can conclude that if the frequency above the maximum output frequency is doubled, zero output will result. This effect accounts for the rapid loss in response in "B" of figure 7 above 5,000 cycles. This rapid drop can be compensated for to some extent by the resonant equalizer previously described so that the frequency response will be like curve "D" of figure 7.

GAP LENGTH VS. SPEED VS. FREQUENCY RESPONSE. It has been assumed in the above discussion of magnet lengths on the tape, that the reproduce head gap is of constant length. If the reproduce head gap is made just half as long, then the situation of case 6 becomes that of case 4. There now is a maximum output at twice the former frequency and it occurs where there previously was zero output.

By this theoretically simple expedient of cutting the head gap length in half, the frequency response has been increased two to one and, with modifications in the equalizer circuits, a response up to 15,000 cycles is now achieved.

There is also a direct relationship between frequency response and tape speed. If the tape speed is doubled, the frequency response is also doubled. Gaps in modern heads for sound reproduction are no more than 0.00025 inch long. Frequency response up to 2.0 megacycles may be achieved by the use of still shorter gaps and higher tape speeds.

However, there is much more to the problem of successfully recording and reproducing high frequencies than merely making the gap shorter and the tape velocity higher. Due to losses in the record head, it is difficult to design a system which will supply sufficient bias to the tape when the bias frequency is on the order of 7.0 megacycles.

Again, in machines of this type, extremely short gap lengths result in practically no flux interception by the head ring. Consequently, the voltage set up in the reproduce circuit is extremely small, and to obtain an adequate signal, the highest caliber amplifier commercially available is needed.

Record head gap length is not critical because the impression left on the tape at any point is the last one it receives as it leaves the influence of the gap.

SIGNAL-TO-NOISE RATIO. In a recorder, there is always a certain amount of noise in the background when the tape is reproduced. In a

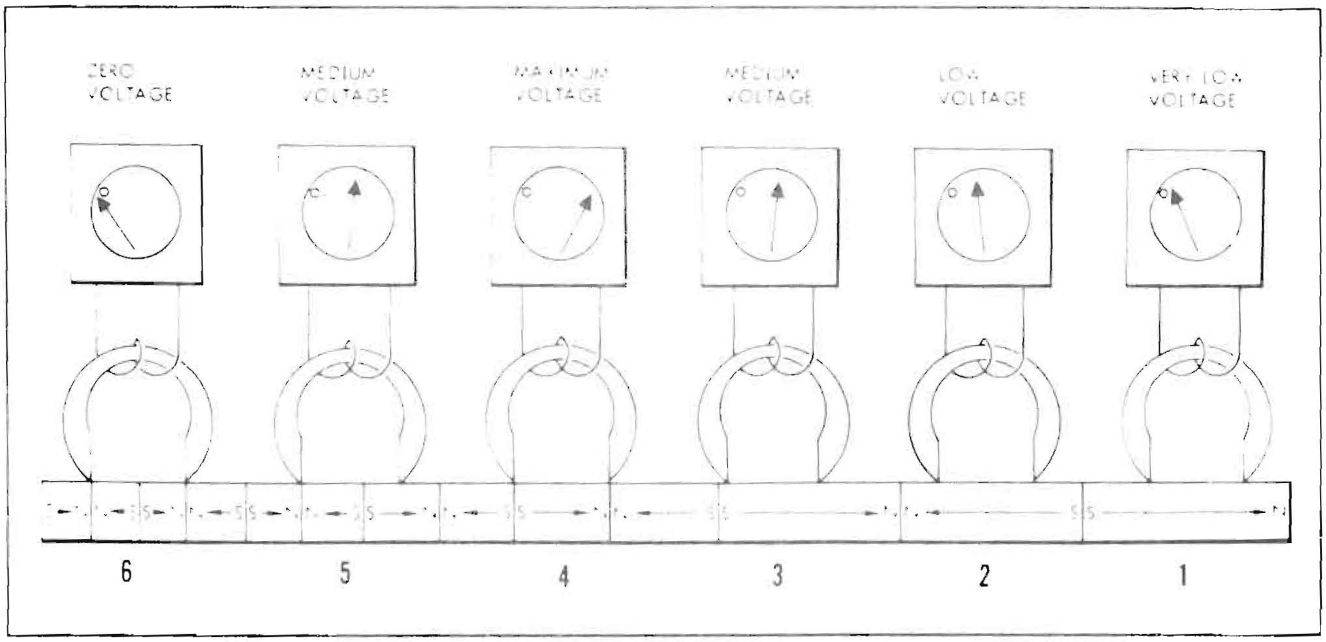


Figure 11. Gap Length Losses

good machine, this noise cannot be heard in the presence of even the weakest sounds which are to be reproduced. In a poor machine, the noise may be so high that only the very loudest sounds can be heard. The ratio between the strength of the recorded sound, commonly called the "signal", and the strength of the residual noise, is the signal-to-noise ratio. This ratio is expressed in decibels.

Most of the noise in a tape recorder arises from tubes, resistors and from alternating current fields caused by transformers and motors. There is also a certain amount of noise arising from the tape itself. This noise can be detected by listening with and without the tape in motion.

The signal-to-noise ratio is measured with relation to some standard intensity of recording on the tape. This intensity generally is that which will produce a known and measurable amount of distortion, such as "one per cent harmonic distortion".

TAPE SATURATION. There is a limit to the intensity to which a tape may be magnetized. If the current driving the record head is increased beyond a certain point, the tape does not retain any increased magnetic impression. Because of this, it is not possible to overcome excessive residual noise by recording the signal at a higher level. After the signal strength increases beyond a certain point, it is no longer faithfully recorded on the tape.

HIGH FREQUENCY PRE-EMPHASIS. By pre-emphasizing the high frequency components of speech and music, an improvement in signal-to-noise ratio may be achieved. Extremely high frequency sounds generally exist at low energy levels, so it is possible to boost their strength in the recording circuit without danger of saturating the tape. In order to make them sound natural when reproduced, it is necessary to pull them back down by means of a complementary equalizer in the reproduce amplifier. A complementary equalizer reduces the high frequency amplification, and in so doing, reduces the objectionable noise mentioned above. This results in an over-all improvement in signal-to-noise ratio.

ERASURE. A distinct advantage of magnetic tape recording is the property of tape which permits it to be erased and re-recorded. A piece of magnetized iron may be demagnetized by subjecting it to a decaying, alternating magnetic field. To provide this field, a coil of wire can be connected across an ordinary 60 cycle line source. If the piece of iron is inserted into the center of the coil, where the magnetic flux is most intense, and then slowly drawn out, it will experience a progressively weaker field until it is too far from the field to be influenced by it. As it is being drawn out of the coil, the iron will be magnetized in a different direction each time the polarity of the field reverses. As the field experienced by the iron is slowly reduced, its impression on the iron will slowly diminish until it makes no impression and the iron is demagnetized.

Magnetic tape is erased in the same way. An erase head is often included in the recorder for this purpose, but reels of tape can be bulk erased by placing them on a degausser, a device similar to the demagnetizer described above. The erase head is very much like a record or reproduce head, but it has a much larger gap. As the tape passes over the head, it is alternately saturated, removing any previous recording. As the tape is drawn away from the gap, the field it experiences gradually decreases until the tape is demagnetized. See figure 12. In a typical recorder, the erase head is placed just ahead of the record head, providing a single operation which removes the old recording and records a new one. In a high speed machine, it would be necessary to furnish the eraser with extremely high frequency current. Because it is difficult to obtain enough power at high frequencies, erase heads are not furnished on high speed machines and a bulk eraser must be used.

OTHER METHODS. Only one method of recording information onto magnetic tape has been covered in this discussion—magnetizing the tape in direct accordance with the amplitude of an input signal. Two other methods are, 1) the frequency modulation and, 2) pulse duration. These methods are used in instrumentation work, but are almost nonexistent in audio applications.

TAPE DRIVE MECHANISM. Any variation in tape speed, either when recording or reproducing a signal, will cause a distortion in the output. To reduce this distortion to a minimum, tape drive mechanisms are designed to reduce tape speed variations.

Figure 13 shows an elementary tape drive system. When a signal is being recorded or reproduced, tape speed variations are reduced by holding the tape against a capstan which turns at a constant velocity. Before reaching the heads, the tape passes over a roller with a flywheel attached to the roller's shaft. The flywheel helps filter out minor speed variations caused by variable friction in the supply reel spindle, tape scraping against the supply reel flanges, and by the tape being wound unevenly on the supply reel.

This elementary tape drive is called an open loop system because of the long open path of tape between the inertia idler on the left and the capstan on the right. For many applications, an open loop system does not maintain a sufficiently constant velocity. One of its inherent weaknesses is

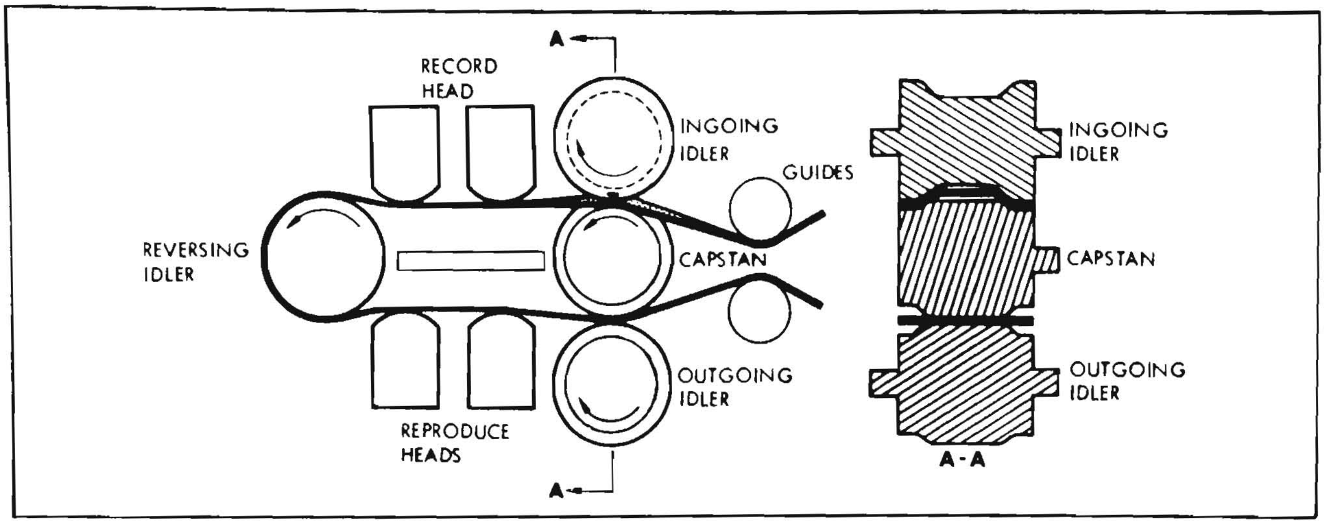


Figure 14. ISOLOOP Drive

in figure 14 shows the shapes of the capstan and capstan idlers. When entering the loop, the tape is held against the relieved edges of the capstan by the grooved idler, but when leaving the loop, it is clamped to the center of the capstan. Since the center of the capstan has a greater peripheral velocity than the edges, the tape must move past it slightly faster than at the edges. This velocity difference causes the elongation of the tape within the loop. The elongation is so slight that it is well within the elastic limits of the tape and causes no permanent deformation.

BIASING IN MAGNETIC TAPE RECORDING

By JOHN G. McKNIGHT/Ampex Corporation

How to select the optimum bias for best low-level response, high output, and reduction of dropouts. Bias frequencies, circuits, and problems are included.

WHEN a magnetic field is applied to certain kinds of materials—such as the coating on a piece of tape—some of this magnetic energy is *stored* on the tape. In other words, the tape coating becomes a permanent magnet. The surface flux from this "magnet" can be detected without in any way changing the stored energy. This particular attribute of detecting without changing is what makes magnetic tape recording possible.

Why "Bias"?

When we look at the relationship between the magnetizing (recording) field and the stored magnetization (Fig. 1A), a defect immediately becomes obvious—there is a tremendous non-linearity. This would cause unbearable harmonic and intermodulation distortion of recorded speech or music signals.

The earliest attempts to reduce this distortion involved applying a d.c. bias to the tape so that the linear portion of the curve from *A* to *B* could be used. Here only about one-third of the curve is used and the presence of the large d.c. magnetization made the recording noisy, thus the signal-to-noise ratio was poor.

A better d.c. biasing scheme was discovered. The tape can be magnetized to saturation in one polarity and the recording head can carry a d.c. bias which *counteracts* this original saturation, bringing the magnetization back to approximately zero. When an a.c. field is added, the magnetization is approximately proportional to this added a.c. value, and linear recording is achieved. However, it is difficult to exactly balance out the d.c. and some noise is left.

A much better method is that of a.c. biasing. The tape is automatically left in a demagnetized state and the full potential signal-to-noise ratio can be achieved. The principle of a.c. biasing was described (but not used for magnetic recording) by Steinhaus and Gumlich in Germany in 1915. A.c. biasing for magnetic recording was discovered but never used practically by Carlson and Carpenter in the USA in 1921, and again by Nagai, Sasaki, and Endo in Japan (1938). Practical utilization came with the re-discovery by Braunmuehl and Weber in Germany in 1940.

Early papers and books on magnetic recording attempted to explain the effect of a.c. biasing through mathematical models, analogies with a class AB push-pull amplifier, and graphical models considering major and minor hysteresis loops of the magnetic material. These explanations are all somewhat magical and of doubtful value. A much clearer visualization of the effect of a.c. biasing can be gained using the process of "ideal magnetization" (also called "anhysteretic magnetization").

For simplicity's sake, let us consider a flexible "bar magnet" made by cutting off a length of blank tape, say 4 cm long. The "bar" can be magnetized in a solenoid carrying a known amount of direct current; the resulting permanent magnetization left after the current is removed can be measured by means of a fluxmeter. When we perform this experiment, and plot the permanent magnetization resulting from various magnetizing currents, we get a curve as in Fig. 1A, showing the great non-linearity.

Suppose that while the direct magnetizing current is applied we add an *alternating* magnetizing current, which we then reduce to a zero value before turning off the direct current. The resulting permanent magnetization is shown in Fig. 1B for different values of the alternating current. Clearly we have accomplished two things: we have greatly increased the sensitivity (the magnetization for a given d.c. magnetizing current), and we have made the magnetization a linear function of the d.c. magnetizing current. Thus, with this system, an undistorted recording can be made. In this experiment, the d.c. represents the signal to be recorded and the a.c. represents the a.c. bias. There is only one major difference in an actual tape recording. In our experiment, the a.c. field decreases while the d.c. field remains constant. If we were to use a magnetic ring-core head on a tape recorder to magnetize a piece of tape pulled past the head, we would find that the a.c. and d.c. fields would die out *together*.

If we go back to our solenoid system and repeat our experiment, but now with both fields decreased simultaneously, we would find the curves of Fig. 1C. Increasing the a.c. up to a certain point has the same effect as before but beyond this point the magnetization decreases.

This magnetization process is exactly equivalent to what actually happens in a tape recorder at low frequencies. At high frequencies, on the other hand, the process becomes very complicated, because the d.c. (signal) field is changing while a particle of tape passes across the recording gap. Fig. 1D demonstrates the 1000-Hz output of a tape recorder at 38 cm/s (15 in/s). Increasing bias current increases the output up to the point of maximum sensitivity (also called "peak bias"), then further increases in bias current *decrease* the output.

The choice of the "best" bias current for practical operation of a tape recorder depends on several factors, because the bias current affects not only sensitivity but also the frequency response and the distortion of the recording process.

One extremely important fact must be pointed out here: all of the relationships in biased recording depend on the relative dimensions of the tape-coating thickness, the recording head gap length, and the recorded wavelength.

1. The tape-coating thickness ranges from about 5 μm (0.2 mil) for triple-play tape through 12 μm (0.5 mil) for standard tape, to about 22 μm (0.87 mil) for high-output tapes. The ratio of the thickest to the thinnest is 4 to 1.

2. The recording head gap length ranges from 1.5 μm

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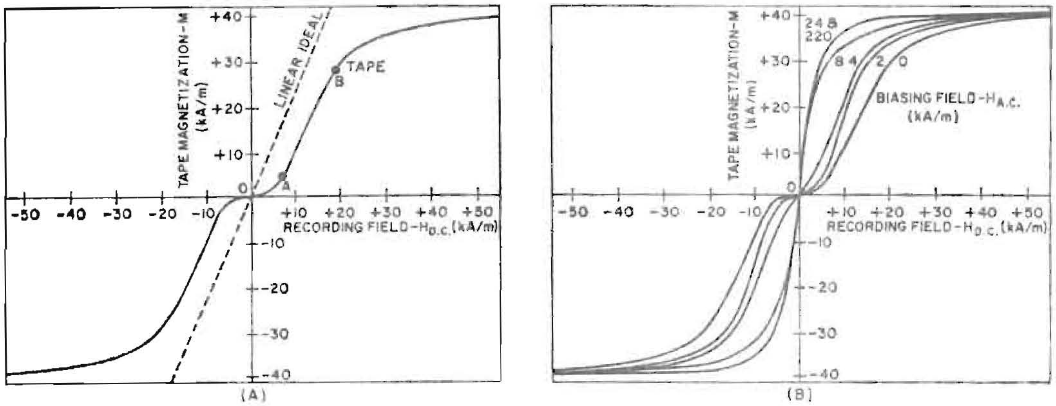
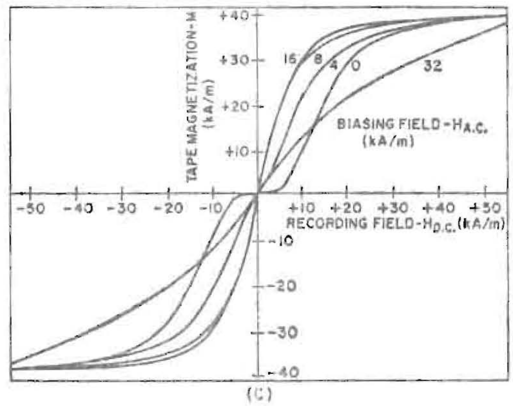




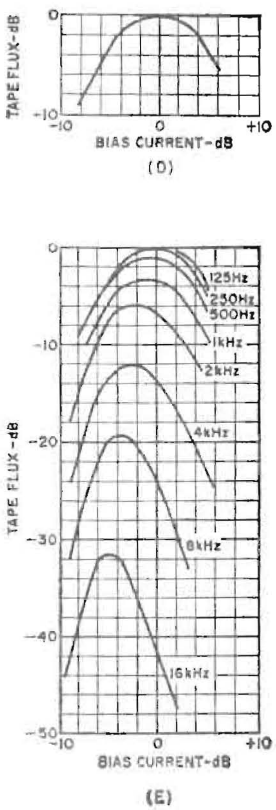


Fig. 1. (A) An unbiased tape is inherently non-linear. (B) When a.c. bias is added in various amounts to the d.c. (signal), the curves are as shown. In this case, the d.c. remains while the a.c. decreases. (C) Same as (B) except that both d.c. and a.c. decrease, simulating actual tape recorder. (D) Output rises with increasing bias to a peak then falls off. (E) Output vs bias current at a number of frequencies using unequalized (flux-sensitive) system, showing the shift required in the bias for maximum high-frequency sensitivity.

(60 μin) for slow-speed, combination-head recorders, through 3 μm (120 μin) for normal combination-head recorders, to 25 μm (1 mil) for professional recording-only heads. The ratio of longest to shortest is 16 to 1.

3. The recorded wavelength (= tape speed in recording/frequency in recording) ranges from 4 μm (160 μin) to 500 μm (200 mils) at 4.76 cm/s (1⅞ in/s) for a frequency range from 12 kHz to 100 Hz and from 25 μm (1 mil) to 10 mm (0.4 in) at 38 cm/s (15 in/s) for a frequency range from 15 kHz to 40 Hz. Altogether the ratio of wavelengths is 2500 to 1!

In the day when recording was primarily professional, that is, 38-cm/s (15 in/s) speed, with 12-μm (0.5-mil) tape coating, and 25-μm (1-mil) recording-head gaps, one could show general relationships and draw general conclusions for optimum operation. Things are not now so simple. We shall have to be content to show specific trends for specific conditions, and simply realize that other conditions will yield different data and conclusions.

The particular magnetic properties of the tape coating are also important and they affect the frequency response, distortion, and the signal-to-noise ratio that is obtained.

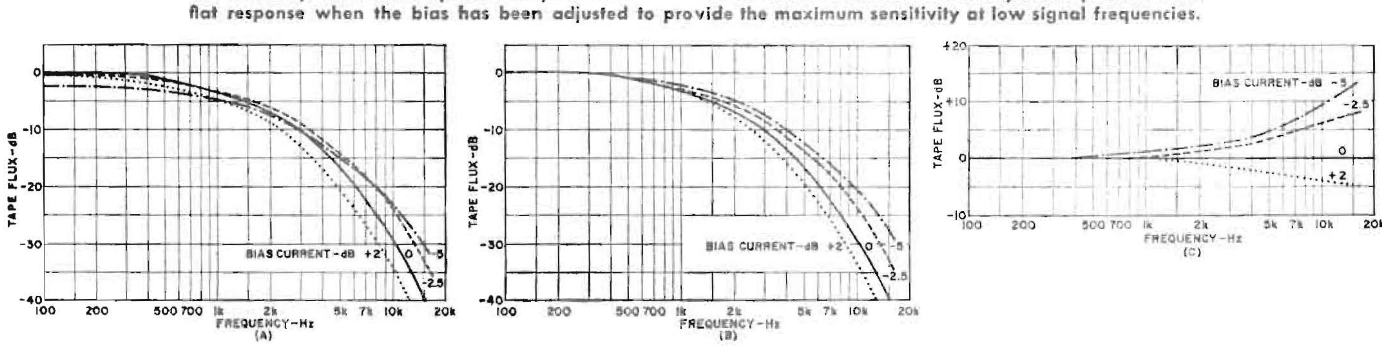
Effect of Bias on Frequency Response

A basic unequalized experimental recorder would use constant recording head current *vs* frequency to produce a constant recording field *versus* recording frequency. A basic unequalized experimental reproducer would have an output proportional to the flux on the tape. For instance, by means of a loss-free short-gap ring-core reproducing head plus an integrating amplifier with constant flux, the head voltage rises 6 dB per octave. But the integrating amplifier response falls 6 dB per octave. Therefore, the two effects compensate and the output voltage is flux-proportional.

Suppose we draw the output *versus* bias current curve at a number of frequencies, as in Fig. 1E. We would see these things: 1. At all frequencies, the output rises with rising bias current, then falls off. 2. The current for maximum sensitivity is the same over a wide range of *low* frequencies (long wavelengths), then, as frequency increases (wavelength becomes shorter) the maximum sensitivity occurs at lower and lower currents.

This data can be re-plotted as a frequency response (Fig. 2A). The generally drooping characteristic shows that the system must be equalized to compensate for short-wavelength losses. Fig. 2B shows the relative responses if the recording field were changed to give the same tape flux at low frequencies for each bias current. We see that low bias current gives the *least* high frequency losses, and therefore would require the least amount of equalization. Therefore,

Fig. 2. (A) Frequency response with different bias currents showing the need for equalization. (B) Same as (A) but with outputs at low frequencies adjusted to same level. (C) Same as (A) but with the system equalized for a flat response when the bias has been adjusted to provide the maximum sensitivity at low signal frequencies.



from *only* a frequency-response standpoint, biasing for maximum sensitivity at the highest frequency would be best. When the system is equalized for the maximum low-frequency sensitivity bias point, changes of bias would change the equalized response as shown in Fig. 2C. Lowering bias increases high-frequency response and *vice versa*.

Effect of Bias on Distortion

Fig. 1B shows that at low bias the curves are non-linear and with increasing bias they become more linear. The measured harmonic distortion at low frequencies shows this effect (Fig. 3A).

Harmonic distortion measurements above one-third of a recorder's bandpass are, of course, meaningless since the distortion (primarily third harmonic) is eliminated. High-frequency non-linear distortion can be measured, however, by the CCIF intermodulation method. Two equal-amplitude high-frequency tones, say f and $f + \Delta f$, are used. If we let f = 300 Hz, then the frequencies could be 10,000 Hz and 10,300 Hz. In the output, we look for the second-order intermodulation frequency component at $f - \Delta f$, which would be 9700 Hz in this case. This frequency is caused by the same non-linear phenomenon which causes third-harmonic distortion, but this frequency is *inside* the system bandpass. Fig. 3B shows the output for 2% IM distortion *versus* bias current, for 500-Hz, 2500-Hz, 5000-Hz signals, using a 9.5 cm/s (3¾ in/s) tape speed, standard tape, and a 5-μm (200 μin) combination recording head gap length. The 0-dB bias current is that which gives maximum sensitivity at 500 Hz.

This data shows the difficulty of improving the high-frequency response by lowering the bias current. The response at lower levels is improved (see Fig. 3B), but the maximum output for a given distortion at mid-frequencies is greatly diminished. Operation at −3 dB bias, for instance, increases the 5-kHz maximum output by almost 3 dB, but decreases the 500 Hz maximum output by 4 dB, thus the mid-frequency signal-to-noise ratio is compromised in order to gain improved high-frequency performance. With separate recording heads, the problem still exists, but is not so severe.

Effects of Bias on Dropouts

When recording, a tape nodule or a dust particle causes the tape to be lifted away from the recording head, the biasing field is, in effect, decreased. If the system is underbiased (say at −2 dB in Fig. 1D), then a small loss of bias causes a large loss of recording sensitivity, and a large dropout of the recorded signal at all frequencies. If, on the other hand, the system were operated in the overbiased condition (say at +2 dB of Fig. 1D), the loss of contact would decrease the biasing field, but this would result in a compensating *increase* in recording sensitivity, thus the dropout would be reduced.

Hence, we have a conflict—best response at low levels dictates low bias current, greatest output for a given distortion dictates a medium bias current, and reduction of dropouts dictates a high bias current. In professional recorders, high-speed recorders with separate recording heads, there is little problem. Best operation comes from biasing at 0 to +2 dB *re* bias for maximum sensitivity at low frequencies. In home recorders—slow-speed recorders with combination recording heads—there is a real conflict and some compromise must be made. Different equipment manufacturers do this differently and extended frequency response may mean high distortion.

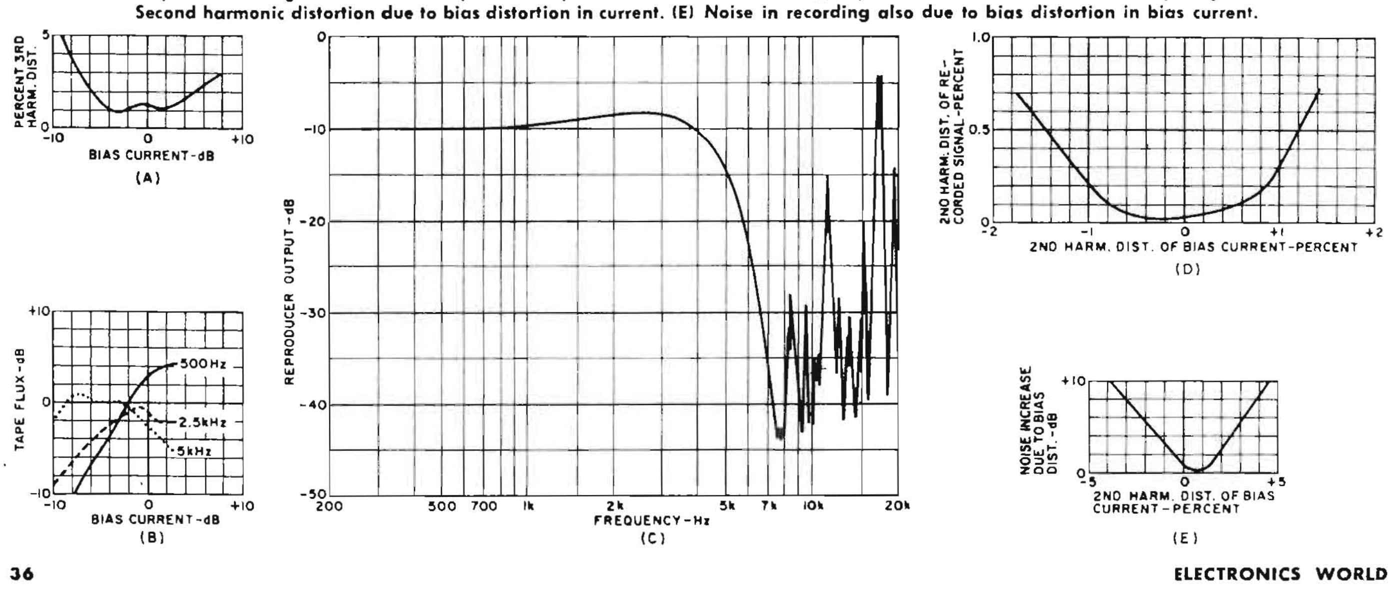
The Bias Frequency

The bias frequency should be as high as possible for two reasons. First, lower bias frequency causes the background noise to increase: at 19 cm/s (7½ in/s) tape speed, the use of bias frequency of about 100 kHz (or more) reduces this noise to nearly the minimum amount. Second, at high recorded frequencies, the harmonic distortion which is created at high recording levels by the tape and recording amplifiers produces audible beats with the bias frequency and these beats are recorded on the tape. A frequency-response run at high levels may look like Fig. 3C. The response above about 8 kHz is, in fact, a series of bias beats. This 4.75-cm/s (1⅞-in/s) recorder uses a 67-kHz bias frequency.

This problem may be especially troublesome when one attempts to make tape recordings from an FM-multiplex tuner. Both 19- and 38-kHz signals are present in the multiplex unit and may get through to the tape recorder. If these are of large magnitude, the bias beats will occur. Several solutions are possible including better filtering of the multiplex carrier in the tuner and low-pass filtering in the tape recorder input circuit. If the multiplexer is well-balanced, so that only the 38-kHz is of concern, the choice of a 95-kHz bias frequency will place the beats above the audible frequency range.

If the bias waveform has even-order harmonic distortion, a d.c. signal is recorded on the tape. This has the bad effect of causing second-harmonic distortion as shown in Fig. 3D. A tape noise is also added, as shown in Fig. 3E. The noise consists of "cracks and pops" (*Continued on page 75*)

Fig. 3. (A) Low-frequency third-harmonic distortion. (B) Maximum output for 2% second-order CCIF IM distortion. Reducing bias for improved high-frequency output results in reduced low-frequency output. (C) High-level frequency response showing "bias birdies"—spurious outputs above 8 kHz in this 1⅞ in/s recorder with 67-kHz bias frequency. (D) Second harmonic distortion due to bias distortion in current. (E) Noise in recording also due to bias distortion in bias current.



Biasing in Tape Recording

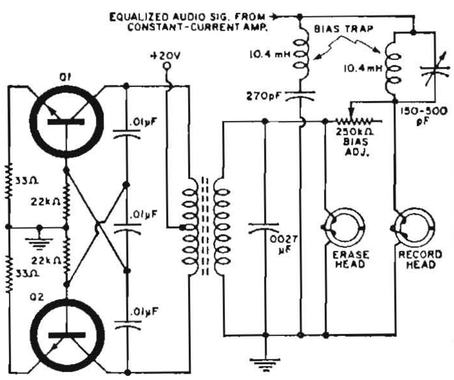
(*Continued from page* 36)

caused by irregularities in the tape coating; it is therefore very much a function of the tape quality.

When the bias is a.c.-coupled to the recording head, any *average* d.c. is eliminated. Unfortunately, the *peak* bias amplitude may still be asymmetrical and this leaves a d.c. flux on the tape.

The bias oscillator circuit shown in Fig. 4 is a common astable multivibrator circuit with a center-tapped transformer, in place of the normal collector resistors and a capacitor, added to complete the parallel resonant circuit with the transformer. This tuned circuit not only sets the frequency of oscillation but also makes the signal sinusoidal. Because the circuit is push-pull, the even-order harmonics, which will cause distortion and noisy recordings, are greatly reduced. The emitter resistors are added to balance the gain in the two transistors to further reduce the generation of even harmonics. ▲

Fig. 4. A typical bias-oscillator circuit using transistors.



Sound Talk®

A Technical Service to the Industry from the makers of Scotch Magnetic Tape

Volume I
No. 2
1968

HIGH FREQUENCY BIAS REQUIREMENTS FOR MAGNETIC TAPE RECORDING

Magnetic recording tape provides a superior method for the permanent recording of information, but it is limited by the natural phenomena of magnetic properties. Fortunately, the shortcomings created by this magnetic phenomena can be compensated for by the use of electronic measures. This bulletin will make no attempt to explore the mathematical or theoretical realms of magnetic recording, but will present a simplified explanation of high frequency bias, its requirements and limitations, and methods of adjustments.

Every magnetic medium exhibits a non-linear characteristic because the magnetization, resulting from an exposure to a magnetic field (such as that produced by the recording head), is not directly proportional to the strength of the field. This non-linear characteristic, if not corrected, would result in severe distortion of the audible recorded information. The use of a high frequency bias current; applied through the recording head, is the standard method of compensating for the non-linearities in the transfer of electro-magnetic signals onto magnetic recording tape.

The high frequency bias signal is usually generated by an oscillator circuit in the recorder electronic system and is added to the signals generated by the microphone or supplied by the recorder input circuits. The bias is a high frequency, usually 30 to 100 kHz (KiloHertz), which is above the range of hearing. Therefore, during playback of only the bias signal, one would not hear or identify any tones which would identify its presence. By adding the bias signal to the audio signal, a resultant signal is produced (Fig. 1). In most recorders, the two signals are simply combined without any form of modulation. The resultant signal is what the record head inductively converts from electrical signals into magnetic fields which influence the magnetic tape.

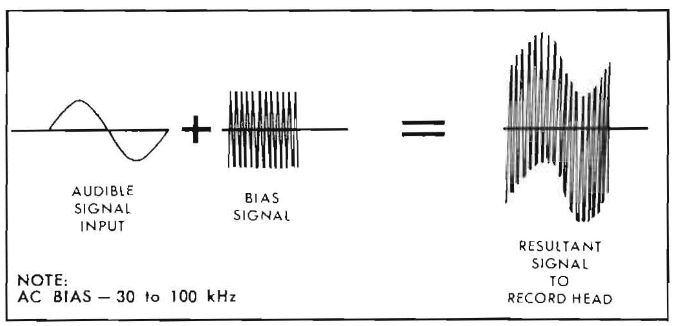


FIGURE 1. PRODUCTION OF RESULTANT SIGNAL

As previously stated, every magnetic medium exhibits a non-linear characteristic. This non-linearity is best illustrated by the Transfer Characteristic Curve which is mathematically derived from a family of hysteresis loops (Figure 2). The hysteresis loops and transfer curve indicate the degree of tape magnetization which results from an exposure to a magnetic field such as that produced by the record head. The transfer curve also indicates that the non-linearities exist only at the extremely low signal level (center portion of the curve) and at the very high signal levels (saturation areas) which are at the extreme ends of the curve. The remainder of the curve is relatively straight and allows linear and proportional transfer of magnetic signals.

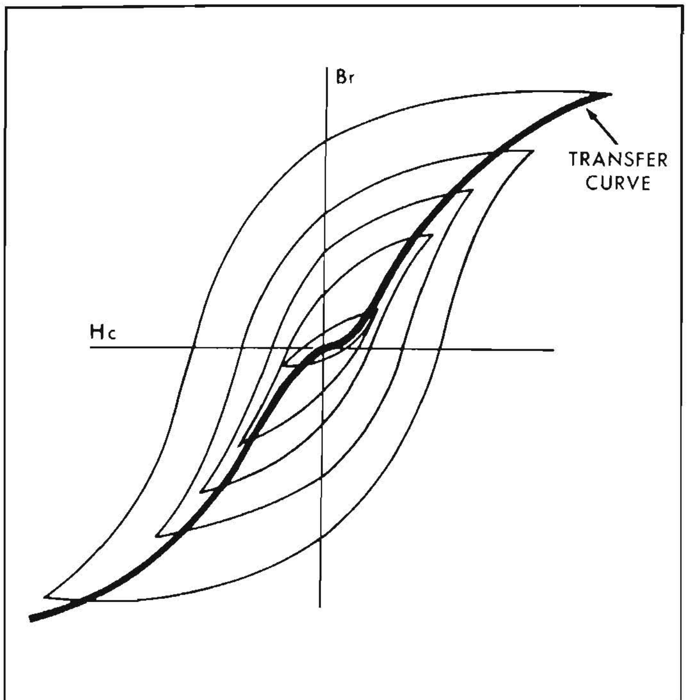


FIGURE 2. TRANSFER CURVE DERIVED
FROM A FAMILY OF HYSTERESIS LOOPS

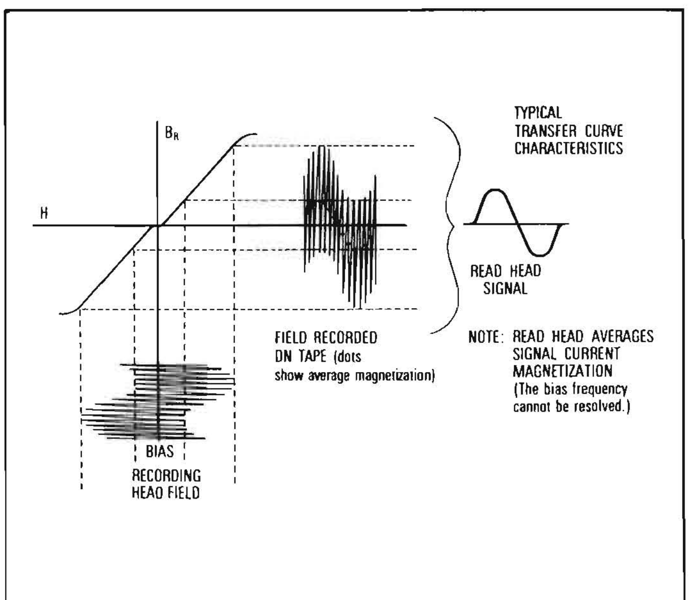


FIGURE 3. RECORDING TAPE TRANSFER CURVE

The transfer curve shown in Figure 3 illustrates the resulting tape magnetization from a magnetic signal generated by the record head. The curve is typical of those for recording tape and no attempt is made to show non-linearities and signal losses created by either the record head or recorder electronic systems.

As the magnetizing force increases (greater record head output in terms of magnetic flux field intensity) the resulting tape magnetization also starts to increase. Notice that the vertical segments of the transfer curve are relatively straight. It is within these straight segments of the curve that undistorted recording takes place. The straight segments indicate that a linear and proportional relationship exists between a given input and the resulting output. This relationship may change for different types of tape because of differences in the magnetic properties exhibited by various oxide coatings.

The straight portions of the curve continue until either saturation in the positive or negative directions occurs. At the saturation points, no effective additional tape magnetization will ocur even if the magnetizing force continues to increase. Recording into the saturation levels may produce distortion, tape noise, and reduce frequency response.

To visualize the recording process, the transfer curve illustrates the resultant signal waveform (sum of bias and input signals), and its transfer across the curve to form the recorded signal waveform (Figure 3). Observe that the signal with bias essentially bridges the "zero-point" and the low signal response portion. The bias position across the curve allows the signal changing portions of the input waveform to fall onto the linear segments of the curve.

The shift of the input waveform across the transfer curve to form the recorded signal waveform shows that the non-linear segment is essentially removed by the bias signal, and the recorded signal is relatively distortion free. Also, it can be visualized that either a low or high bias condition will drive the signal onto the non-linear segments of the curve and will cause distortion.

With a low bias condition, (Figure 4) the low level input signals may fall into the "zero-point" region and either may be severely distorted or not be reproduced. In a high bias condition, (Figure 5) the high frequency response will decrease. The high frequencies will distort sooner or go into saturation because of a phenomenon called "self-erasure" which will be discussed in a future *SOUND TALK.* Also, the signal-to-noise ratio may be reduced causing undesirable tape noise.

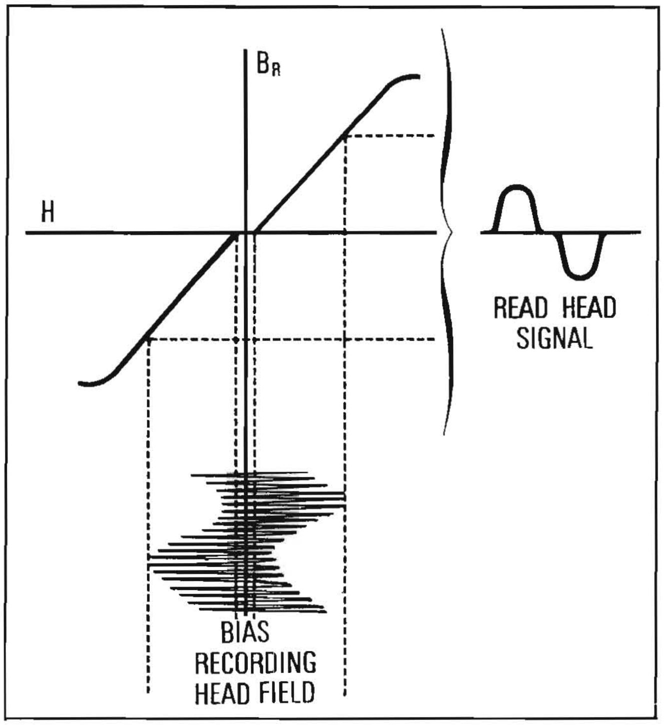


FIGURE 4. UNDER BIAS CONDITION

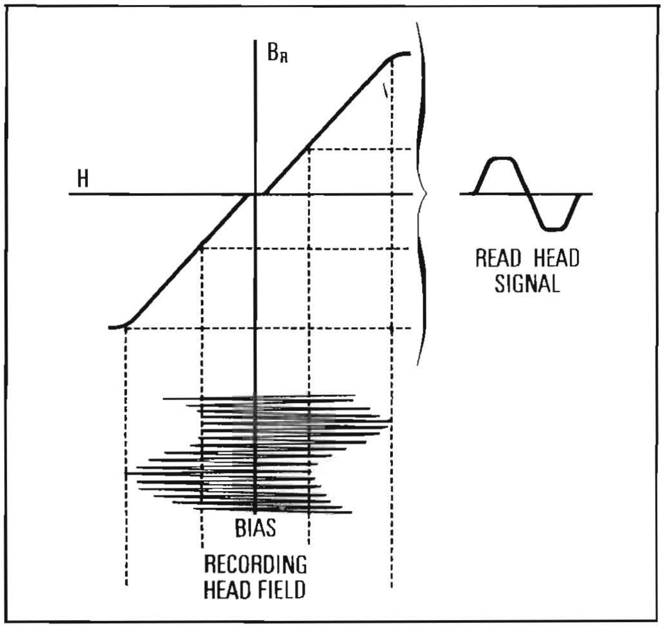


FIGURE 5. OVER BIAS CONDITION

The transfer curve is typical of most magn~~etic~~ recording tapes but each particular type of tape will exhibit different slope, "zero-point" region, as well as different saturation peaks. The differences of the curve shapes are created by the individual magnetic properties exhibited by each tape type. As the shape of the curve changes so do the bias requirements.

A low coercivity tape has very steep linear segments and will require less bias current. On the other hand, a high coercivity tape has relatively shallow linear segments which require a greater bias current input. Because of the differences in tape magnetic properties the slope of the curve changes and the proper bias level required to eliminate distortion will change accordingly.

To evaluate the changes of bias requirements involved with different types of tape, the tape's wavelength response must be considered. Bias current is required to eliminate distortion but is also directly involved with frequency response and output. In terms of response and output, the bias requirement is related to tape construction such as; type and thickness of coating, quality of oxide dispersion forming the coating, and smoothness of the coating surface.

As a general rule, high frequency response can be improved by using a tape with a high coercivity oxide, relatively thin coating depth and a smooth (specially prepared) coating surface. These improvements of high frequencies may have an opposite effect for the low frequencies to the extent that they may not be reproduced with the same efficiency. This situation becomes apparent in the bias curves (Figure 6).

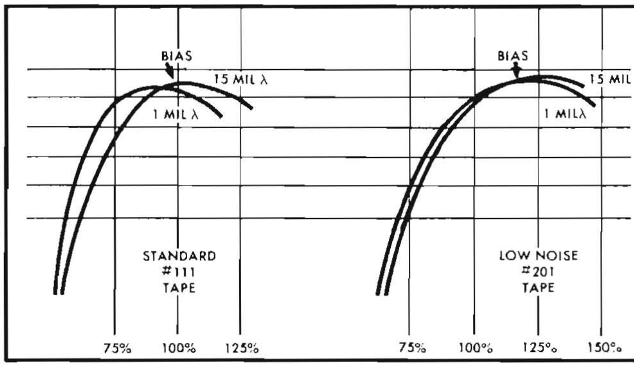


FIGURE 6. BIAS CURVES

Because of the slight differences that may occur in the reproduction of the different frequencies, the actual bias setting is of a selective nature. The ideal situation would be one where the bias setting is at the point of peak output for all frequencies. Note that a bias setting is easily accomplished for the low noise tape as shown in the bias curves (Figure 6). For this particular tape both the high frequency (1 mil wavelength) and the low frequency (15 mil wavelength) output peaks coincide with each other allowing the bias setting to be at the overall output peak.

In the case of the standard tape, the high and low frequency (short and long wavelength) output peaks do not coincide at maximum output. The bias setting could be at either output peak or at the mid point. In normal recorder adjustment however, the bias setting most often used is at the output peak of the longer wavelengths. This setting is justified because the greater percentage of

recorded information is in the low or mid-range portion of the frequency spectrum. To compensate for any unbalance in response output, the equalization settings of the recorder are adjusted until the overall output frequency response is flat.

TYPICAL BIAS ADJUSTMENT PROCEDURE

The bias settings shown in the illustration indicate only a relative bias level comparison between two different types of tape. The percentage value relationship will generally hold true for most recorders. Specific information on bias adjustment or settings is impossible to enter into here because of the large variety of recorders in use. Most recorders have their own individual requirements and specifications for bias current (or voltage) adjustments. If a bias level adjustment is attempted – care should be taken to assure correct settings and the recommendations of the recorder manufacturer must be precisely followed.

As mentioned in the preceding paragraphs, the low-midrange frequency (longer wavelengths) output peak is generally used to obtain the most desirable bias setting. The normal adjustment frequency (for 7½ inches/sec. tape speed) is 500 to 1000 Hz. This audio signal is available from an audio, function, or signal generator which most electronic repair facilities have available.

The following adjustment of recorder bias is typical of many machines now in use. For stereo machines, the adjustment procedure must be repeated for both channels. Before attempting any adjustment, be sure that the machine is operating properly, the record and playback heads are clean and in good condition, and thoroughly review the manufacturer's service manual. The bias adjustment range, location, and function of controls, and the operation and scale of the output meters (VU meters) must be understood. Since the bias setting is determined by the type of recording tape, establish the basic type of tape most often used in your particular recorder. Prepare the machine for normal recording at 7½ ips with a low signal level input (approximately 20 db below tape saturation).

Set "Gain," "Record Volume," or "Level" adjustments low to avoid the possibility of recording in the saturation levels. Adjust the signal generator (1000 Hz signal source) for a low voltage output and connect to the recorder input terminals. If the recorder is a 3-head type, while recording the 1000 Hz signal, listen to the recorded signal. Slowly increase the bias current (or voltage) and observe any increase of output as indicated on the VU meters. An increase of intensity of the playback signal should also be heard. Continue to adjust the bias, starting at low output, until the maximum output signal is observed. Continue to increase bias until the maximum output signal is observed. Continue to increase bias until the output begins to drop, indicating an over-bias condition (Figure 6), and return the bias setting to the point of maximum output.

If the recorder is a 2-head type, the set up procedure is similar except that a series of short recordings, each with a change in bias current (or voltage), is made and played back. A simple method is to voice identify the recording segment and bias setting and record the 1000 Hz signal for 10 seconds, readjust the bias current and record and identify another segment. Repeat this procedure for low to high bias current (or voltage). Then play back all the recorded segments noting which one has the greatest fidelity and intensity, and set the bias accordingly.

The recommended bias setting for most recorders is where maximum output is indicated for the 1000 Hz signal. This setting coincides with the low frequency (long wavelength) output peak as shown in the response curve illustrations.

After the correct bias adjustment is obtained, a corresponding equalization control adjustment may, in some cases, be required to compensate for differences in overall response. Usually a simple listening test of recorded material will determine if the overall response is correct.

SUMMARY

High frequency bias current to the recording head is required because of the non-linear characteristic exhibited by most magnetic media. Its major purpose is to compensate for these non-linearities and allow distortion-free recording. Correct bias setting allows undistorted recordings on magnetic tape to the limits established by the record head or the recorder electronics. Proper bias adjustment also assures a better signal-to-noise ratio and optimum frequency response. Maximum performance and fidelity are direct results of high frequency bias.

If at any time additional information on this topic is desired, it is available by simply writing to:

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LITHO IN U.S.A. WITH 3M OFFSET PLATES

a Care package for

AUDIO RECORDERS

by Gene Titterington
Field Service Engineer
Ampex Corporation

Recognizing that instructions for the care of magnetic tape recorders are indelibly imprinted on the memory of every recording engineer, we are nonetheless persisting in our belief that somewhere, somehow, these instructions should be restated. For those who have but recently joined us, of course.

Here, then, is a review of the professional audio recorder—what it is supposed to do, what care it should receive, some tips on checking up on it, plus a few casual indicators of trouble for engineers willing to frown knowingly at some point prior to total disintegration of the recorder in service.

Simply put, the professional magnetic audio tape recorder is a system in which signals in the frequency spectrum to which the human ear is tuned are recorded on magnetic tape for later reproduction. The name of the game is "what goes in should come out!" The fact that what comes out is remarkably similar to what goes in is what makes the magnetic tape recorder the useful tool that it is. In calling it a "professional" recorder we are simply defining the category of recorder used by the professional recording or broadcast engineer in the normal course of his day to day activities. But . . . if the professional wishes to apply the same care to his home recorder, we have no objections.

There are some peculiar twists to the process, though. Sometimes more comes out than expected. Noise, for example. And a surplus of low frequencies. At the same time *less* comes out. High frequencies get lost in the shuffle of loading signals on tape and getting them off again.

Some of this gaining and losing is cancelled out by some pretty nifty adjustments made by the manufacturer and recording engineers operating as a team. But there are some residual effects which are undesirable and these are the ones we'll attempt to thwart herein.

Mind you, we're not going to solve all of your problems, we'll just tell you some of the things to do to avoid some of them. And maybe point you in the right direction.

PREVENTIVE MAINTENANCE . . . Three Easy Steps

First, let's assume immediately that all professional audio recorders perform as specified and that performance as specified is satisfactory. Our job: to unseat those malevolent forces which suddenly appear to upset our assumptions.

Most readers will recognize three basic principles right off:

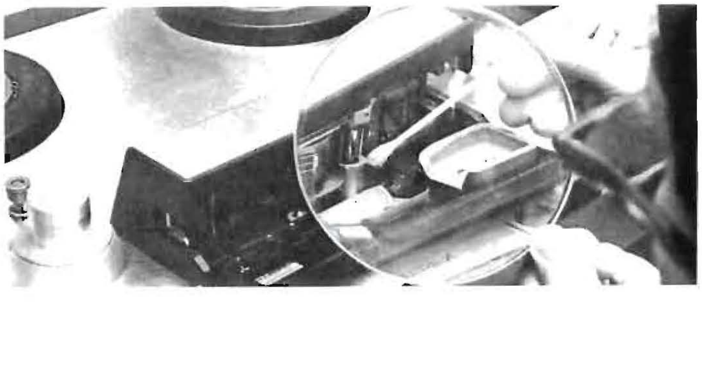
1. A recorder with clean heads, guides, capstan and surfaces is less susceptible to problems caused by dirt and oxide than a dirty recorder.
2. Proper and regular demagnetization of all elements in the tape path is quite likely to eliminate problems caused by magnetized heads, guides, etc.
3. A properly lubricated transport will not be over-lubricated or under-lubricated. It has also been known to run better as well.

When analyzed, these three basic statements will reveal one startling fact: together they constitute the entire preventive maintenance routine. Anything above or beyond this constitutes inspection, checking or troubleshooting.

This in no way implies that inspection, checking and trouble-shooting are not to be indulged in—not at all. It just pays dividends to know where one leaves off and the others begin. And while the preventive maintenance routine can be delegated to an assistant, the really careful engineer will do the next step himself: the inspection.

TAKE A LONG HARD LOOK

You'll get no quarrel from anyone by claiming that a good visual inspection can reveal many, many little pieces of information that together tell a significant story about the condition of the recorder.



While there is no way to describe it adequately, a properly adjusted tape transport literally sings a song of well-being. You can feel it. By the same token, an ailing recorder can cause the hackles on the back of your neck to stand out straight. You're uncomfortable being in the same room with it.

The well-behaved transport on close inspection will be passing tape in an absolutely flat path- flat in that motion is nearly imperceptible. It is this comfortable sensation of the rightness of things plus the beautiful, smooth flow of tape that encourages the engineer to proceed knowing that *today* things will go well.

At this point, the engineer can check the braking system. Two successful smooth stops in a row signifies that, by golly, he might have it made. And so he continues to exercise the transport through all of its modes and in the several speed ranges involved.

Note that the engineer in checking "stops" is also checking "starts" in approximately a 1:1 ratio. In both cases, the stop/start times can be checked against the manufacturer's spec. Again, the well-adjusted transport will be a delight to behold.

Satisfied that the transport functions are just short of perfection, the engineer can now continue his inspection by removing the tape from the machine and preparing for a thorough examination of the entire transport.

Two tools are helpful. Good light and a man sized magnifying glass. There need be no shame connected with the use of the glass. After all, the idea is to see what's going on.

From the engineer's vantage point all manner of wonderful things show up in the glass. (And you thought you cleaned the system, didn't you?)

Dirt and oxide particles stare balefully back from hidden corners. Here's a piece of torn tape tucked away. Safe enough where it is, but what if it should move and lodge itself smack dab against a head at a critical instant?

Get rid of it! And any others you may find.

And while you are getting rid of the scrap of tape, you've a perfect right to ask where it came from. One scrap could be a piece knocked off the end of a tape during a fast rewind--several pieces of similar size and shape *could* indicate a burr on a contact surface somewhere--missed at the last inspection.

And that oxide where did *it* come from? Poor cleaning? Or is it newly shed--a sign of trouble?

Now the value of the glass really shows. A careful check of stationary guides and the heads will reveal any signs of wear. If slot-wear is present yet recorder performance is satisfactory, there may be no cause for alarm. Leaving well-enough alone applies. It may be sufficient simply to make a note that the wear *is* taking place and watch for further developments. But if the engineer is contemplating a change in head alignment, those wear slots will present some real problems.

Tapes will not track smoothly through the misaligned slots. Buckling, bowing or warping of the tape could result with an attendant loss of intimate tape-to-head contact. High-frequency response drops off quickly and physical tape damage is a good possibility.

Under the assumption made in the beginning, the recorder under survey is in decent condition. We have observed no signs of wear. But we're not through yet. Some additional checks should be performed.

Head alignment and electronics are still unknown quantities. While these items appear to be in proper working trim, the "let's make sure" checks are not difficult to perform, nor need they require much of your valuable time.

TEST TAPES . . . Your Best Friends

Select the proper test tapes needed (reproducer alignment tapes recorded at the proper speeds). Ideally, you should use test tapes with track configurations matching that of the recorder. You're already aware of the fringe-effect that occurs when using full-track tapes to check multitrack recorders. Low frequency response is magnified and it is next to impossible to equalize for a flat response. (Remember even with the right format tapes the "bumps" will still be there.)

Thread the alignment tape carefully and follow the voice instructions on the tape. In most test tapes, signals are provided for checking head azimuth, frequency response and the operating level, not necessarily in that order. Make the essential adjustments for both speeds, using the tape made for each speed. (Although the NAB equalization curves are identical for 15 ips and 7½ ips, the frequency response adjustments must be made with separate tapes to assure accuracy.)

In using test tapes, the confident voice on tape may sound more authoritative than the condition of the tape warrants. *Know your test tape.*

TENDER LOVING CARE FOR TEST TAPES

While test tapes are masters so far as the recorded signals are concerned, they are fragile things. Once they leave the environment in which they were made, they are susceptible to the same damage as any other tape. They not only wear out in use, but even deteriorate magnetically on the shelf. Shelf deterioration can be minimized by proper storage, but only care in use can successfully combat physical damage to test tapes. Manufacturers are cautious in expressing life-expectancy figures. Fifty to a hundred plays seems to be a safe figure. Losses as high as 5 dB have been noticed at the hundred play mark. Offsetting this are tests where tape life has been extended well beyond one-hundred plays when normal clearing and degaussing routines are followed. Professional quality heads generally will extend the life of test tapes. This would indicate the need for caution in using test tapes on heads of doubtful quality--at least those test tapes you depend on for use with your professional gear.

Under no circumstances should a test tape be used on a machine prior to cleaning and degaussing. Remember that short wave-length flux literally rides on the oxide surface. Wear it thin and you've lost the high frequencies. Even if no wear occurs, dirt causes loss of intimate contact and again, there go the highs.

Running test tapes on magnetized surfaces offers more trouble. You can erase the highs and replace them with noise rather easily.

A word about the efficiency of head degaussers should be dropped in here.

New AMPEX HD-16 Degausser

With the wide availability of low-noise tapes, noise reduction systems, and 16 channel (or more) recording systems, noise or signal damage caused by magnetized elements in the tape path is more than ever noticeable. Tests have shown that the old familiar head degausser is not doing the job adequately. Special, more effective degaussers will undoubtedly reach the market in the near future. Until they are available, the professional must use what he has. Multi-channel head systems that can be removed from the transport should be degaussed with the more powerful bulk degaussers. Even the handheld bulk degaussers will do a better job of degaussing parts such as capstans and guides.

In storing your test tapes, rewind them carefully and store them in a magnetically secure environment away from speakers, microphones and other magnetic devices (including magnetic latches on cabinet doors!).

Since test tapes represent one of your primary reference standards, they should be treated as precision tools. You can be sure that's how the manufacturer treats them.

Once you have checked the recorder by means of the reproducer alignment tape, you will have established several points: the azimuth of the reproducing heads is correct, the frequency response has been equalized at each operating speed and you have adjusted the output to the standard operating level.

With all these good things done you can carefully rewind the test tapes at play speed (or store them tail out) and put them away in a secure storage.

IT'S THE SIMPLE THINGS THAT COUNT

See how conveniently our assumption has served us? Since your recorder was assumed to be in good working order, all you've had to do is to perform three simple preventive maintenance steps, a visual inspection *(thorough* visual inspection), and a check of the system using properly configured alignment tapes.

Together, these routines comprise the basic care package for your recorder. Because they are simple routines, they can be repeated often. Others must be performed too, and these routines will generally be spelled out by the manufacturer in the instruction manual.

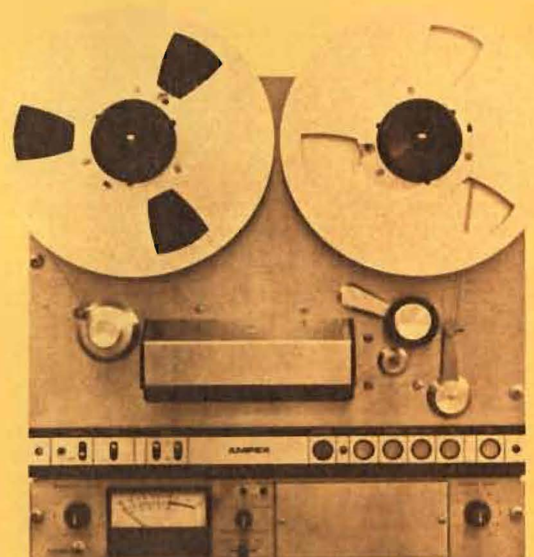
Since most of these more specialized checks and adjustments are peculiar to the machine involved, we won't detail them here.

Instead, we'll make a list of the routines, suggesting the frequency of application, and give the reasons why they should be done. This, then, is a more complete "care package for the magnetic audio recorder."

AUDIO RECORDER SCHEDULE OF ROUTINE INSPECTION AND MAINTENANCE

ROUTINE	HOW OFTEN	WHY
1. Cleaning	As often as desired but certainly no less often than once every eight operating hours.	Clean recorders eliminate a lot of possible problems. Dirt and oxide accelerate wear and degrade performance.
2. Demagnetizing	Should be considered as part of the cleaning routine.	Magnetic cleanliness is as desirable as physical cleanliness. Stray fields can rob you of the quality you put in so carefully.
3. Lubrication	As recommended by the manufacturer. No more, no less. This is no place to exercise creativity.	No one likes a squeaky wheel. Too much lubrication attracts dirt, destroys components.
4. Visual Inspection	Follow your own time-table. In practice the careful engineer is *always* inspecting.	Observation of normal behavior can tune the eye to abnormal conditions. Also, some problems can be observed in development, and corrected before catastrophe.
5. System Check Out (using alignment tapes)	After cleaning and demagnetizing, generally prior to an important session. As the commercial says, "once in the morning does it."	Test tapes are a primary reference and remove any doubts you might have.
6. System Check Out (using manufacturer's check list and flutter test tape)	Follow the manufacturer's instructions. Use flutter test tape after all adjustments to the tape handling system.	These checks determine whether or not adjustments should be made in brake or hold-back tensions, capstan idler pressures, etc. Flutter test checks adjustments in reproduce modes and is a comfortable reassurance that tape is being handled properly.

AMPEX



TEST TAPE APPLICATIONS

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Reproducer Test Tapes: Evolution and Manufacture*

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Reproducer test tapes (also called alignment tapes or standard tapes) are used to standardize the azimuth, frequency-response characteristics, and recorded levels of magnetic sound recording systems. Informal working standards and formal standards are discussed, with emphasis on changes in standards and possible resulting confusion. The manufacture of reproducer test tapes is described, including special requirements for heads and blank tape, and the methods for determining the azimuth and the flux vs frequency. Handling techniques which minimize the chance of damage are also described.

INTRODUCTION Recorded material must reproduce satisfactorily, not only on the machine which made the initial recording, but also on all other similar equipment. Thus, each reproducer must be adjusted to the same specified standard reproducing flux-freq.resp. and operating level. The purpose of reproducer test tapes is to make possible the practical measurement and adjustment of magnetic tape reproducers.

The reproducer test tape is used to adjust the reproducing head azimuth as well as the reproducing amplifier equalization and gain ("operating level"). Other types of test tapes (not further discussed here) are the flutter test tape, used for measuring flutter to the NAB Standards[1] (it is also used according to American Standard Z57.1-1954); and the recorder adjusting or reference medium test tapes, which are unrecorded tapes of average characteristics used for adjusting the bias current and recording equalization of a recorder.

EVOLUTION OF REPRODUCING FREQUENCY RESPONSE

Standardizing organizations have been almost as prolific in their recommendations as the industry has been in developing hardware. The one-of-a-kind custom equipment of a few years ago has often created a working standard simply by usage, and formal standards have then followed. In the beginning there was only full track, ¼ in. (6.3 mm) tape width, and one or two tape speeds. Now sixteen different reproducer test tapes are available from a single manufacturer (Ampex). Adding the proposed test tapes according to the new NAB Standard, plus proposed changes in International Standards, this number will soon rise to twenty-seven, and this does not even include tapes for every track configuration,[2] or cartridge tapes, or the flat sheet medium for spot announcements called CUE-MAT™.

Experience has shown that old standards cannot be simply dropped when a new standard is adopted by one, or for that matter by all, standardizing organizations. Even if the old "standard" became so only by virtue of popular usage, it does exist, libraries of tapes made to agree with it exist, equipment exists, and the manufacturer has to provide the corresponding test tapes for many years. A good example of this is the 3.75 ips (9.5 cm/sec) situation, where three different standards[3] are now in use in the United States and one more internationally: *viz.* high-frequency equalization time constants t_2 of 200, 140, 120 and 90 μsec, with or without bass equalization t_1 of 3180 μsec.

THE NAB STANDARDS

In 1953 the National Association of Broadcasters published a description of a standard reproducer for 15 ips (38 cm/sec) use, based on an idealized ferromagnetic reproducing head and an amplifier of specified response. The reproducing flux-freq.resp. had time constants of $t_1 = 3180$ μsec and $t_2 = 50$ μsec (transition frequencies of $f_l = 50$ Hz, $f_u = 3200$ Hz).

At the 15 and 30 ips (38 and 76 cm/sec) speeds then prevalent, the wavelength remained relatively long even at high frequencies—a 1 mil (25 μm) wavelength[4] (15 kHz at 15 ips) was the shortest encountered in general audio work. This meant that even without using a reproducer test tape, the error might be small if the reproducing amplifier were adjusted to the specified response, and the reproducing head assumed to be ideal. (The test tape *was* needed to adjust head azimuth and operating level.)

Experiments indicated that a 15 ips test tape suffered

* Presented October 12, 1966 at the 31st Convention of the Audio Engineering Society, New York.

very little degradation with careful use. Primary and secondary reference response tapes, carefully stored, were employed to calibrate test tape production equipment over long periods of time.

Because several different reproducing freq. resp's were in use for 7.5 ips (19 cm/sec) in the early 1950's, the NAB did not standardize a reproducing freq.resp. for this speed. Eventually the freq. resp. originally used for 15 ips (t_1 = 3180 μsec, t_2 = 50 μsec) also became generally accepted for 7.5 ips, thus establishing a "standard by usage".

The 1953 NAB Standard made no mention of the recorded level. The Ampex "operating level"[5] was originally determined by measuring distortion, and would thus be a function of the particular tape used. A 15 mil (380 μm) wavelength signal producing 1% third harmonic distortion on a selected batch of then-current 3M-111 tape became the flux reference for the "Ampex operating level". It was recognized very early that the operating level of the Ampex Test Tapes had to be held at a constant absolute flux level rather than at a constant distortion, in order to produce practical compatibility of levels in the recording industry. Thus, although tape has changed, the operating level flux of test tapes has remained extremely constant to the present time. Fortunately, the tape selected in the original determination of long wavelength operating level had greater distortion at a given flux than present-day tapes; therefore the amount of distortion experienced today with most available tapes at operating level is less than the original 1%. The Ampex operating level recording has a short-circuit flux of approximately 200 nanowebers per meter of track width (= 20 millimaxwells per millimeter, or 125 mMx for a tape 248 mils wide).

In 1965, the NAB published a new Standard which reaffirmed the reproducing flux-freq. resp. time constants for 15 ips (t_1 = 3180 μsec, t_2 = 50 μsec), and recognized past industry usage of this same reproducing freq.resp. for 7.5 ips. The new NAB Standard does call, however, for a change of the reproducing freq. resp. time constant t_2 at 3.75 ips from 120 μsec to 90 μsec. This represents a 2.4 dB reduction of high-frequency response in the reproducer, which in turn necessitates a corresponding increase of 2.4 dB of the recording pre-emphasis in order to maintain a flat overall response. This in turn suggests that a recording level reduction might be desirable at this speed. On the other hand, it would be confusing in practice if the NAB Reference Level were different from the existing Ampex Operating Level. Also, among recording companies and broadcasters there exists a great variety of methods for mixing and for reading program levels: some recording companies record in the "RED" at all times, and others make it a practice never to allow meter readings to exceed −3 on the vu meter. It seems doubtful that many will want to change their long-established level practices. Therefore it would seem advantageous for the NAB Reference Level to be the same as the presently accepted Ampex Operating Level.

Since the NAB Standard specified the Reference Level in terms of a "vault reference recording" rather than in terms of flux in standard units, one must await the availability of the approved NAB Test Tapes in order to find out what the new NAB level will in fact be.

MANUFACTURING REPRODUCER TEST TAPES

In order to manufacture reproducer test tapes, one must obtain high quality heads and tape; determine the correct head azimuth; and calibrate the reproducing system which is used to measure the reproducer test tape flux vs. frequency.

Magnetic Heads

A chief requisite in the production of reproducer test tapes is the availability of a good source of custom-built recording and reproducing heads. Without a facility such as a head development laboratory, it would be difficult (if not impossible) to obtain the necessary calibration and production hardware.

Heads must be selected for greatest possible edge straightness, gap regularity[6,7] and consistency of pole-piece depth. In the case of full-track tapes, the recording head cores must be wider than the tape in order to assure recording across the entire width of the tape. Gap depth of the recording head must be constant across its entire width in order to insure even flux distribution across the tape. Reproducing heads for calibration work should be of the high density type (that is, with very thin layers of bonding material between laminations). For 0.5 mil (= 12 μm) wavelength recording the bonding material should be less than 0.5 mil in thickness; any thicker material will cause noticeable unrecorded "tracks" where the tape is contacted by the non-magnetic bonding material, which in turn will cause amplitude variations when adjusting overall response and thereby increase the possibilities of error.

Head gaps must be microscopically examined, lamination by lamination, and deviations from the average center of the gap measured at both the leading and trailing edges. Imperfect heads are rejected.

Selection of Tapes

Blank tape for test tape production must exhibit even coating thickness and a good degree of surface polish, in order to have amplitude stability of the recorded tones.

Other very important requirements are precise straightness of the tape edge, and accurate tape packing on the reel. Otherwise, the recorded azimuth will vary to the point where the "azimuth" section on the test tape will be unsuitable for adjustments. By carefully selecting properly slit tape, one can hold average azimuth variation to about ±1'; amplitude variation caused by this amount of azimuth disagreement will then be less than ±0.5 dB with a 12 μm (0.5 mil) wavelength full-track recording.

Azimuth Determination

Correct head azimuth is obtained when the head gap is exactly at right angles to the edge of the tape; this in turn produces a recorded track which is exactly perpendicular to the tape edge. (This assumes that the tape *has* a straight edge which can be referenced. If the tape is improperly slit, wound, and or stored, the edge will be wavey and relative azimuth will vary.)

Some very early test tapes were made with incorrect azimuth. The error was not too serious (especially at

the then-current 30 and 15 ips speeds), but was corrected because it was quite noticeable at the slower speeds.

Azimuth loss is plotted[8] in Fig. 1; the loss is seen to

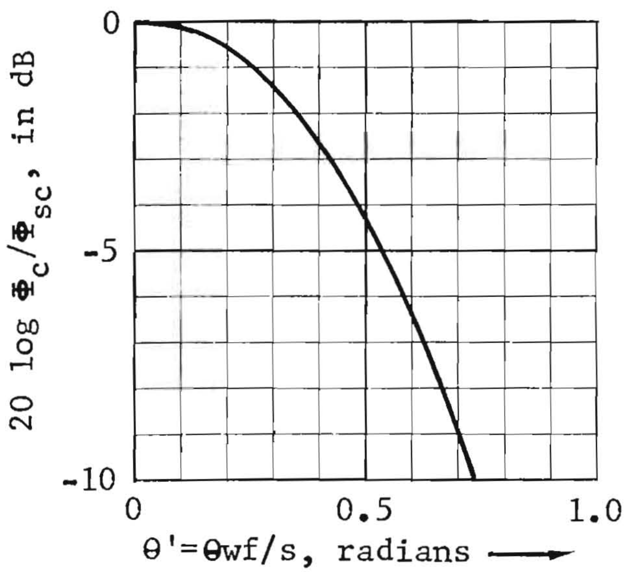

Fig. 1. The azimuth loss, $\Phi_c(\theta')/\Phi_{sc} = (\sin\pi\theta')/\pi\theta'$; or, in dB directly, $\Phi_c(\theta')/\Phi_{sc} = 20 \cdot (\theta')^{2.32}$, where $\theta' = \theta wf/s$, in radians, θ is the angle between the recorded track and the reproducer gap, in radians (3440 minutes of arc = 1 radian), w is the track width, and s the reproducing speed (w and s in the same units), and f the reproduced frequency in Hz.

increase with increasing angle, track width, and frequency, and with decreasing speed. This curve is shown again in Fig. 2, this time plotted *vs* tape speed, with the other conditions fixed: the loss is seen to increase as speed decreases, from about 0.4 dB at 15 ips to 5.5 dB at 3.75 ips. Similarly, Fig. 3 shows the loss *vs* track width with other conditions fixed: an unmeasurable loss with 20 or 40 mil tracks increases to a 5.5 dB loss with full track heads. Thus, for a given tape speed and frequency, the wider the track, the more critical the azimuth adjustment becomes. From this, it follows that high-frequency amplitude variations due to misalignment, poor tape slitting or winding, or poor guiding will generally be worse with wide-track systems.

A number of methods have been used to determine the azimuth of a recorded track. The simplest in principle is to make the recorded track visible by means of carbonyl iron powder,[9] by softening the binder with amyl acetate,[10] or by using a tape viewer.[11] The visible track can be checked for perpendicularity to the tape edge by means of a toolmaker's microscope.[12] The major difficulty is that tape with a perfectly straight edge does not exist; therefore many measurements are required in order to determine the average angle. (This method is also helpful in demonstrating edge curl, which may happen when imperfect tape winding allows the tape to rest against one reel flange.)

If tape is simply turned end-for-end, the azimuth error will be in the same direction—it does not reverse. Therefore some means is needed for producing a "mirror image". The first and most satisfactory method is shown in Fig. 4. It consists of the following steps:

1. A full-track, short-wavelength signal is recorded,

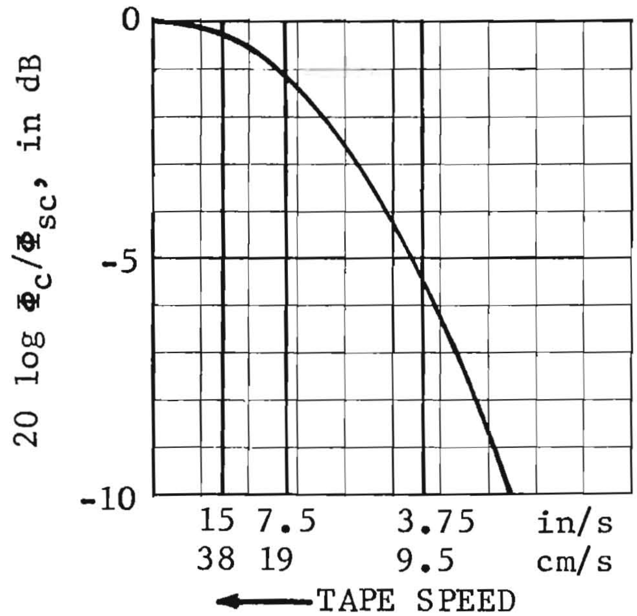

Fig. 2. Azimuth loss vs tape speed for $\theta = 2'$, w = full-track ¼ in. tape (6.3 mm), f = 15 kHz.

using a combination recording and reproducing head with an arbitrary azimuth setting. An indicator and an angular scale should be added to the azimuth adjustment screw of the head assembly to show the relative azimuth settings: the angle for this first recording should be noted.

2. After the signal is recorded, the full-track tape is rewound with the oxide surface in contact with a blank piece of tape.

3. The two tapes are then run through the machine, with a small amount of bias current applied to the head. This causes a "mirror image" of the original signal to be printed on the adjacent blank piece of tape.

4. The "printed tape" is reproduced, the head adjusted for this new azimuth, and the new setting noted.

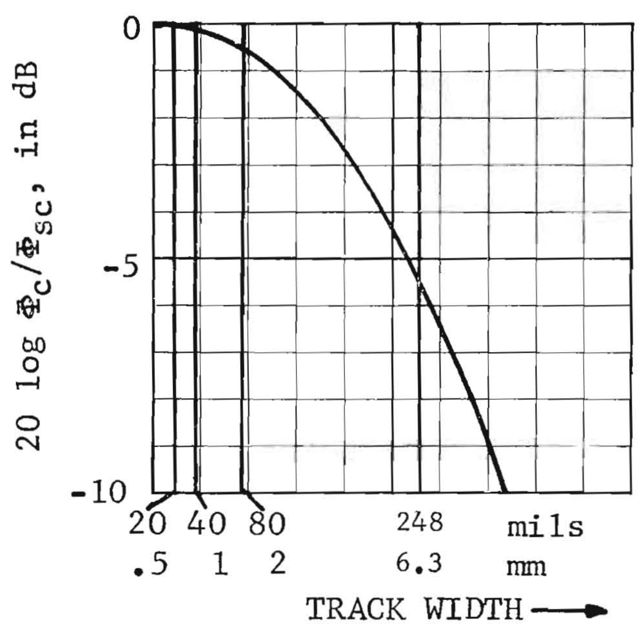

Fig. 3. Azimuth loss vs track width for $\theta = 2'$, f = 15 kHz, s = 3.75 in./sec (9.5 cm/sec).

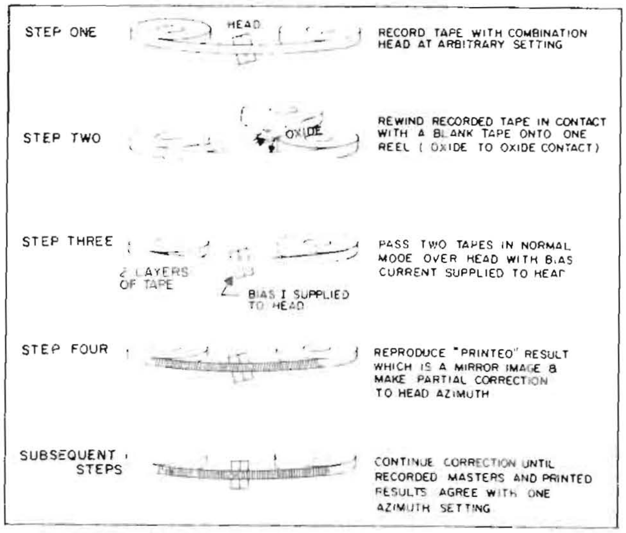

Fig. 4. Azimuth determination by the master and transfer print method.

5. The azimuth is set halfway between the two azimuth angles measured in steps 1 and 4.

6. Steps 1-5 are repeated until "masters" and "prints" both show maximum response at the same setting-- this indicates perpendicularity of the head gap to the guided tape path.

A second method for producing the "mirror image" involves turning the tape over and reproducing the signal through the base of the tape. The adjustment method is similar to that just explained. The problem here is that, at the short wavelengths necessary for accurate azimuth adjustment, the loss of signal through the backing of the tape is so large that it is difficult to find the signal at all. Evans has described[13] a means for making this principle of azimuth determination practical: A two-track combination head is used. (An important requirement not mentioned by Evans is that the two gaps must be exactly coplanar, that is, there must be no gap scatter.) Phase of the two signals is compared, rather than seeking maximum amplitude. If the two signals are combined out of phase, the position of correct alignment results in a very sharp null of output even when a mid-frequency signal (say 3 kHz at 15 ips) is used. Therefore the signal amplitude can be large enough even when reproduced through the tape back.

Finally, experiments have been conducted on a third method for determining azimuth, using heads with a gap at the front and another at the back, and special guides for the tape (see Fig. 5). The front and back gaps of the head must be parallel to one another, and both surfaces must be lapped for good tape-to-head contact. The tape is recorded at the front of the head, rewound oxide-out (B wind), then reproduced by the back gap of the same head. The head rather than the tape thus produces the "mirror image". Adjustments are made as described above until perfect agreement is achieved between the back and front gaps. Guiding problems have made this method unsatisfactory.

DETERMINING THE REPRODUCING FLUX-FREQUENCY RESPONSE

The calibration of the reproducing channel used in making reproducer test tapes generally follows the procedures detailed in the 1965 NAB Standard. First one determines the response of the reproducing head plus electronics from a constant flux input: a flux-inducing loop is attached to the front gap of the head, and a constant current signal vs frequency is applied through the loop. The amplifier can then be adjusted to provide the correct response for an ideal head. (In this measurement, resonance effects of the head and cable are included. It simplifies matters if the playback head resonates well outside the band of interest; this requires a low inductance head, with fewer turns of wire than usual.) When using this flux-inducing method, a de-emphasis network can be used after the reproducing amplifier to produce a flat reading on a vtvm when the reproducing flux response is correctly adjusted to the appropriate standard. A different response is of course needed for each of the many standard curves in use.

A practical head will also have wavelength response errors which must be measured and taken into account. Gap losses and contour effects are measured as outlined in Annex C of the 1965 NAB Standard. These measurements are somewhat involved, and it is best to double-check them. As a further check, one should measure several known heads for later cross reference.

After the losses inherent in the reproducing head are determined, a curve may be drawn showing the deviation from ideal of a particular reproducing system. A recording can then be made which will reproduce in agreement with the calibration curve; in other words, the recording should play back with the same response as the reproducing system.

Once a system is calibrated, a tape may be made for use in adjusting other test tape production machines, for test tape production on a comparative reference basis. Each such machine must produce tapes which have recorded flux identical to that of the tape made on the calibrated system. In production practice, several tapes are made on the calibrated reproducer and used as setup tapes. However, it should be noted that setup tapes do not last long, and must be recalibrated frequently on the original test setup or else replaced entirely.

These techniques all center around the calibration of the reproducing system. Recording current can be varied to compensate for differing tape characteristics.

Production practice at Ampex has shown that each test tape must be made individually: each tape is an original recording, it is not a copy. Of course, the voice announcements are dubbed, but the test signals are

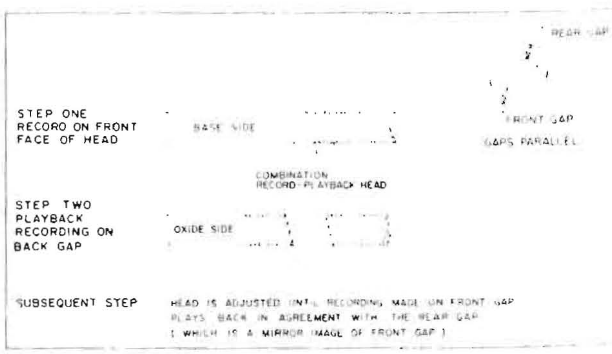

Fig. 5. Azimuth determination by the front back gap method.

supplied directly to the recording amplifiers from a specially constructed oscillator having pre-set switchable frequencies. The voice track is reproduced backwards, and the announcements, along with the tones from the oscillator, are recorded in reverse order. This provides a smooth tape pack since the reel is ready for packaging, with no need for rewinding.

TEST TAPE ACCURACY

Accuracy of Manufacture

Table I lists the usual maximum errors which can be expected for Ampex Test Tapes. These include the uncertainties of the basic measurements in addition to the deviations allowed in manufacturing.

TABLE I. Maximum errors of Ampex Test Tapes.

"Operating Level" Flux	±0.25 dB from one test tape to another; absolute value, 200 nanowebers per meter of track width, ±10%.[14]
Uniformity of Flux Across Tape Width	±0.25 dB of specified value.
Azimuth	±2′ of perpendicularity to edge of tape.
Frequency Response	The short circuit flux is ±0.6 dB of specified response for wavelengths greater than 0.75 mil (19 μm) (frequencies of 10 kHz at 7.5 ips, 5 kHz at 3.75 ips, and 2.5 kHz at 1.87 ips). Accuracy at shorter wavelengths (higher frequencies) may be ±1.2 dB of specified response.
Accuracy of Recorded Wavelength	±2%.

Other studies, made by European test-tape manufacturers, have yielded very similar accuracies.

In practice, test tapes checked at time of manufacture do not show variations of this magnitude. The quoted figures include instrumentation error and 3 months' storage with temperature cycling variations of approximately 60°F to 80°F (15° to 27°C). There are several sources of error in each measurement in calibrating the reproducing system, and in making the test tapes. One would expect these to add in a root-sum-square manner most of the time, but it is possible that all of the errors could be in the same direction, and therefore add directly.

Errors in Test Tapes Arising after Manufacture

Accidental Damage.—Mechanical and/or magnetic damage which will destroy the accuracy of test tapes may occur in playing, rewinding, or storing them. The shorter wavelength (high-frequency) recordings are most easily damaged.

Mechanical deformation of the tape will usually damage the edge of the tape, causing uneven tracking and a constantly changing relative azimuth of the recorded tone. Contact of the tape pack with one reel flange may result in irreparable edge damage. Mechanical distortion due to uneven wind of the tape on the reel is aggravated by high temperatures, and by temperature and humidity cycling.

Magnetic damage (erasure) may occur if tape is stored in areas of high magnetic field (e.g., certain loudspeakers, meters, motors, microphones, etc.). Partial or complete erasure of the tape may occur if it is reproduced on a transport which has magnetized heads or guides, or if the recording and/or erasing heads are accidentally energized while reproducing the test tape.

Normal Wear and Tear.—The effects listed under Accidental Damage may be small enough to cause damage that is not apparent from one use of the tape, yet that with repeated usage will result in a gradual loss of accuracy. The tape surface will also wear (lose oxide) even if the tape transport is perfect. Also, loose oxide may become "welded" to the tape surface, causing increased spacing loss.

When the tape passes around small radii, the mechanical bending may cause some loss of magnetization, especially at short wavelengths. This loss depends on the tape used, but is usually about 0.5 dB at 0.5 mil (12 μm) wavelength.

For example, a test tape which has been carefully handled and played 50 times will have a loss of 0.5 to 2 dB at 0.5 mil wavelength (15 kHz at 7.5 ips). For 100 plays, the loss may be about 3.5 dB at short wavelengths. With more playings and/or slightly defective reproducers, the loss will approach 5 dB or more.

In order to prolong the useful life of the test tapes, Ampex practice is to compensate for some of the losses experienced in normal usage by recording the shortest wavelengths at a level slightly higher than that prescribed in the Standard: a boost of 1.25 dB is used at 0.5 mil (12 μm).

Conclusions about Tape Wear and Damage.—From this information we must conclude that *it is absolutely necessary that test tapes be recalibrated or replaced periodically, no matter how carefully the tapes are handled.*

This experience with test tapes also leads to a practical conclusion about the frequency response of systems working at wavelengths of 0.5 mil (12 μm) or less (e.g., at and above 15 kHz at 7.5 ips, or 7.5 kHz at 3.75 ips, etc.): namely, that, even though a system at these short wavelengths may be adjusted to have flat overall response, true flat response on an interchangeability basis may be difficult to obtain due to errors in the test tapes. Further, even when a system *is* set up to be flat on an interchangeability basis, the short wavelengths recorded on the tapes are fugitive, just as those on the test tapes, and a tape recording at slow speed (3.75 ips or less) which is flat today may well be lacking high frequencies after storage or after a number of playings.

MEASUREMENT ERRORS IN USING A TEST TAPE

Most of the complaints of "defective test tapes" are found to be actually due to errors of measurement technique in using the tapes. A very common error is that of using a full track test tape to measure the frequency response of a multi-track reproducer. The fringing effect causes a rise of up to about 5 dB in the apparent low-frequency response of the reproducer. This error is

sometimes attributed to the test tape; it is in fact due to use of the wrong tape since a multi-track test tape must be used for accurate low-frequency measurements of a multi-track reproducer.

The numerous possible errors of measurement technique are dealt with in detail in a companion paper.[2]

CARE OF TEST TAPES

Tape intended for repeated use in standardization work must be properly cared for if its full usefulness is to be maintained. Physical deformation of the tape can be a serious problem. Edge damage can be prevented by winding the tape smoothly under moderate tension and evenly spaced between the reel flanges. The tape pack should not be wound in contact with one reel flange, as this will result in irreparable edge damage if it is stored in this condition for long periods of time.

Tapes should not be stored in fields from motors or permanent magnets; for example, a tape stored in a cabinet next to a loudspeaker or microphone may be affected. Heads and tape guides should be demagnetized. When a reproducer test tape is used for continuous check-out purposes, such as in production line work, age and wear as described above often become the primary sources of inaccuracy.

ACKNOWLEDGMENT

The author wishes to thank the following Ampex Corporation personnel: Harold Lindsay, Mort Fujii, and George Goodall, for suggestions relative to this paper; and John G. McKnight for editorial revision of the paper.

NOTES

1. All standards referred to in this paper are fully described in: J. G. McKnight, "A List of Published Standards Related to Magnetic Sound Recording", J. Audio Eng. Soc. 15, 254 (July, 1967).

2. The need for test tapes in different track configurations is discussed in the companion paper by J. G. McKnight, "Tape Reproducer Response Measurements with a Reproducer Test Tape". J. AES 15, 152 (Apr. 67).

3. J. G. McKnight, "Absolute Flux and Frequency Response Characteristics in Magnetic Sound Recording", J. AES 15, 314 (July, 1967) Re. p. 12.

4. Wavelength = speed frequency ($\lambda = s/f$). The recorded wavelength, in mil, equals the tape speed in inches per second divided by the frequency in kilohertz; alternately, wavelength in micrometers equals tape speed in mm/sec divided by frequency in kilohertz.

5. The operating level recording on the test tape is used to set the reproducing amplifier gain so that the vu meter reads zero.

6. See Eric D. Daniel and P. E. Axon, "The Reproduction of Signals Recorded on Magnetic Tape", *Proc. IEE* **100**, Pt. 3, 157 (1953).

7. O. Schmidbauer, "Einfluss der Schiefstellung des Spaltes und andere Spaltfehler" (The Influence of Misalignment of the Gaps and Other Gap Defects), in F. Winckel (ed.), *Technik der Magnetspeicher* (Springer-Verlag, Berlin, 1960), p. 55.

8. The very convenient formula shown in the figure caption is good for $\theta < 0.2$ radian (11°), and loss $\lesssim 12$ dB. It is taken from page 407 of F. Krones, "Die Theorie des Magnetspeichers" (The Theory of Magnetic Storage) in F. Winckel, ed., *Technik der Magnetspeicher* (Springer-Verlag, Berlin, 1960).

9. A commercially available form of carbonyl iron powder in volatile solvent is the Ampex Edivue Kit, 50495-01.

10. Technique described by Walter Guckenburg, in "The Process of Magnetization of Magnetic Tape", *JSMPTE* **65**, 69 (1956).

11. For example, 3M's Magnetic Tape Viewer #600.

12. B. F. Murphey and H. K. Smith, "Head Alignment with Visible Magnetic Tracks", *Audio Engineering* **33**, 12 (1949).

13. Arthur G. Evans, "The 'Null Method' of Azimuth Alignment in Multitrack Magnetic Tape Recording", *IRE Trans. on Audio* **AU-7**, 116 (Sept.-Oct. 1959).

14. The measuring method is being refined so that the absolute flux should soon be measurable with an error of only ±2%.

THE AUTHOR

Robert K. Morrison was born in 1925 in Madera, California. He received his B.A. degree from the University of California's College of Letters and Science at Berkeley in 1949. During his undergraduate years he was involved in disk and optical film recording with Picto Sound Company in San Francisco.

Following his graduation, he joined Voice of America in New York City, moving in 1953 to Central California Broadcasters, Incorporated, where he held the position of chief engineer until 1959. At the present time, Mr. Morrison is manager of the Ampex Standard Tape Laboratory in Redwood City, California.

Tape Reproducer Response Measurements With a Reproducer Test Tape *

JOHN G. McKNIGHT

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The reproducer test tape affords the most satisfactory field means of standardizing magnetic sound recording systems. This method is nevertheless susceptible to numerous errors of measurement due to inappropriate test tape (wrong speed, equalization, track format, or test frequencies), and mechanical misadjustment of the reproducer (head height; azimuth and zenith adjustment; and poor tape-to-head contact due to dirt on heads, inadequate tape tension or wrap around the heads, improper vertex adjustment, worn heads, and improper tape guiding). These errors are described, in order that they may be avoided.

INTRODUCTION The measurement, adjustment, and standardization of the frequency response of a magnetic tape reproducer,[1] and the setting of gain and head azimuth are usually performed in the field by the use of a reproducer test tape.[2] For example, Section 2.05 of the 1965 NAB Standard[3] defines the response of a reproducer as the output voltage of the reproducing amplifier *vs* frequency when reproducing the appropriate test tape. In general, this method is quite satisfactory, and is the best one known for this purpose. However, in order to avoid measurement errors during the use of a test tape, it is essential to observe certain special precautions, in addition to the use of ordinary good engineering practices. High- and low-frequency errors of measurement amounting to 3 to 6 dB (or more) are a likely result of improper procedures or the failure to observe needed precautions. Common errors of procedure cause an apparent rise of low-frequency response or a decrease of high-frequency response, or possibly both at once. Therefore, when measurement errors occur, the response will almost always fall with increasing frequency.

Although a new test tape is subject to certain small errors[2] and a used test tape is subject to much larger errors[2] most complaints about defects in the test tapes are in fact caused by errors in the use of the tape. This paper discusses measurement errors resulting from the use of an inappropriate test tape and errors resulting from mechanical misadjustments in the reproducing head.

* Presented October 12, 1966 at the 31st Convention of the Audio Engineering Society, New York.

INAPPROPRIATE TEST TAPE

Test tapes may be inappropriate for use on a given system in any of the following areas: rated tape speed, flux-freq. resp. (equalization), track format, and/or recorded test frequencies.

Tape Speed

It is obvious that a 38 cm/sec (15 ips) reproducer must be tested by use of a 38 cm/sec test tape. It is not so obvious that a multiple-speed reproducer must be tested and adjusted at *each* of the speeds; a response measurement at one speed guarantees nothing about the response at the other speeds. It is commonly assumed that, since the NAB equalization curve is identical for both 19- and 38-cm/sec tape speeds (7.5 and 15 ips), an adjustment at one or the other tape speed suffices for both. This is only approximately true because of the 1:2 ratio of wavelengths involved. Accurate response measurements require the use of both 38- and 19-cm/sec test tapes.

Test Tape Flux vs Frequency (Equalization)

A number of equalization time constants are used in the USA and elsewhere.[1] Although the 19- and 38-cm/sec (7.5- and 15-ips) tape speeds most commonly used in the USA are nearly always used with the NAB freq. resp. (t_1 = 3180 μsec, t_2 = 50 μsec), recent USA changes in 9.5 cm/sec (3.75 ips) equalization, coupled with recent changes in international standards

for 9.5 and 19 cm/sec (3.75 and 7.5 ips), require that the user specify not only the name of the standardizing organization and the tape speed, but also the date of the standard. There is the least chance for error if the actual time constants desired are specified.

While this paper is not concerned with the absolute recorded level, one should be aware that the Reference Level of the proposed NAB Standard Tapes may be lower than that traditionally used on the Operating Level section of Ampex Test Tapes. The flux for the NAB Standard Reference Level has not yet been definitely established. Also, the DIN Test Tapes have a *Bezugspegel* (reference level) that is 1.5 to 3.5 dB higher than the Ampex Operating Level, depending on the intended tape speed. This is because the German volume indicators and equalizations are different from the USA ones.

Test Tape Track Format

All of the proposed NAB Standard Test Tapes, and most Ampex Test Tapes are recorded across the full width of the tape.[4] When these tapes are reproduced by narrower-track heads (e.g., half-track, stereo, or multiple-track heads), a low-frequency measurement error occurs because of the "fringing effect": at long wavelengths (low frequencies) the reproducing head core receives effective flux from the recorded track area outside of the area actually contacted by the reproducing head core. This error is a function of the recorded wavelength (which equals the tape speed divided by the recorded frequency), the particular design of the head shielding, and the geometry of the tape wrap over the head face. For example, Fig. 1 illustrates the rise of

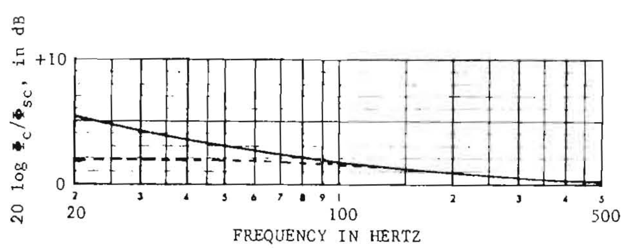

Fig. 1. "Fringing" response rise when reproducing a full-track recording with a half-track reproducer **(solid curve)** and a stereo reproducer **(dashed curve)** at 38 cm/sec (15 ips), where Φ_c is the flux in the head core, and Φ_{sc} is the short-circuit tape flux.

response at 38 cm/sec (15 ips) caused by the fringing when a full-width recorded track is reproduced by a half-track head (*solid curve*), and by a stereo head (*dashed curve*). (The response would be flat if the appropriate half-track or stereo recording were used.) The response rise due to fringing at 50 Hz (wavelength = 7.6 mm, or 300 mil) is +3 dB for the half-track head and +2 dB for the stereo head. The difference between these responses is caused by the difference in the shielding arrangements of these heads: the actual head cores and track configurations are essentially identical. Thus we see that an all-purpose correction curve cannot be found even for one particular track configuration.

In the instance of a four-track head, fringing response rises of 1 to 5 dB, depending on the particular head design, have been observed.

A really satisfactory solution to the problem of producing test tapes for all of the various multi-track configurations of reproducers is yet to be found. Table I below lists eight of the track configurations most commonly used with the three common tape widths. But it should be remembered that at least 11 "standard" (but different) flux-freq. resps. are used for four common speeds. If each flux-freq. resp. were produced in each track configuration, a catalog of 88 reproducer test tapes would be required. And one could add 4.75 cm/sec (1.87 ips), Ampex Mastering Equalization at 38 cm/sec (15 ips), and undoubtedly others too! It is just not possible to manufacture, catalog, and distribute reproducer test tapes for every track configuration, because to do so would make their cost prohibitive. Therefore, reproducer test tapes are all made in the full-track configuration, but relatively few test tapes are made in multi-track configurations.[4]

TABLE I. Commonly used track configurations.

Tape Width *mm*	*in.*	*Number of Tracks*
6.3	0.248	1, 2, 4, 8
12.7	0.50	3, 4
25.4	1.00	6, 8

One means by which fairly accurate data on multi-track reproducers could be determined even though using a full-track test tape would be for the tape recorder manufacturer to include in the instruction manual of each model of multi-track reproducer the response of that reproducer to a *full-track* test tape, when the response is flat with the correct track-configuration of the test tape.

In lieu of this, anyone desiring really accurate low-frequency response measurements of multi-track reproducers (other than with the previously mentioned multi-track tapes) must make his own low-frequency test tape. This is feasible; although the making of accurate test tapes for high frequencies (short wavelengths) is rather difficult, and not at all recommended to the general user, a low-frequency test tape is not too difficult to make accurately if one has accurate general-purpose electronic measuring equipment. The method is described in the Appendix.

Frequencies on the Test Tape

Reproducer test tapes can be made with a sweep-frequency tone, or with a succession of discrete ("spot") frequency tones. Since a graphic level recorder is required to realize the benefits of the sweep-frequency tone, and since such a recorder is not commonly available to tape recorder users, the spot frequency method is used in making test tapes. The use of spot frequencies assumes that the frequency-response of the reproducer is smooth and continuous throughout the whole frequency range. This assumption is usually valid—but not always. If the reproducing head is unshielded, and the corners of the pole pieces are rectangular, the true long-wavelength (low-frequency) response[5] will be as in Fig. 2; if the reproducing head gap is perfect, the short-wavelength (high-frequency) response[6] will be as

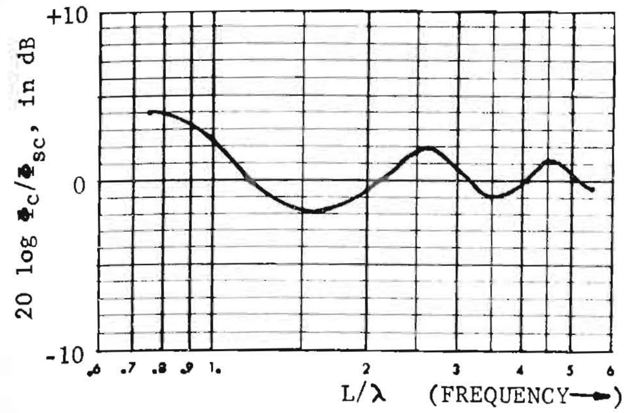

Fig. 2. Theoretical long-wavelength response of an unshielded reproducing head with rectangular pole pieces, where L is the length of the head core face and λ is the recorded wavelength.

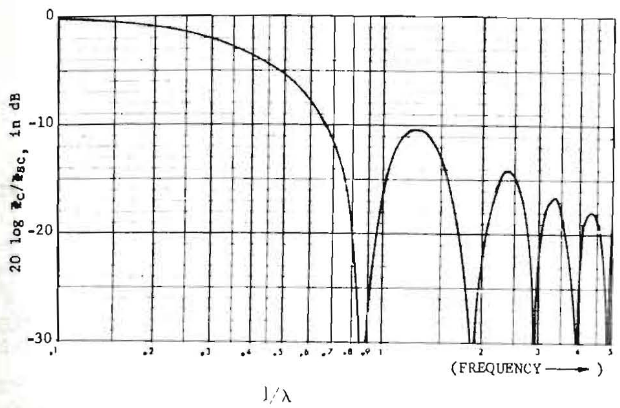

Fig. 3. Theoretical short-wavelength response of a reproducing head with a long gap, where l is the mechanical gap length.

in Fig. 3. Thus, the response at both very long and very short wavelengths may show large undulations.

A practical example of an extreme case is given by the measurements made on an 8-track, 6.3 mm (¼ in.), 9.5 cm/sec (3.75 ips) reproducer: in Fig. 4 the solid line shows the response of the reproducer to a full-track test tape; the data points are connected by the usually assumed smooth curve, and the response looks satisfactory. Next (dashed line) the response was measured at the same spot frequencies with an actual 8-track test tape; having removed the fringing effect by using the correct track width, the response fell 4 dB at 50 Hz; the usual smooth curve was again drawn. In Fig. 5, the solid line shows the true response, as measured with a sweep-frequency test tape; the dashed curve shows the response assumed on the basis of the spot frequencies on the test tape. The error due to using spot frequencies instead of a sweep frequency is seen to be ±3 dB over much of the range from 50 to 500 Hz, and 7 dB at 130 Hz. This shows that a complete and accurate measurement of reproducer low-frequency response may require a sweep-frequency test tape, since spot-frequency measurements may be grossly in error in some cases. The method which is described in the Appendix may be used to establish the response for making such a sweep tape.

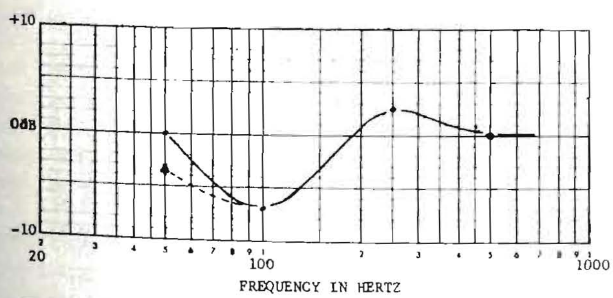

Fig. 4. Frequency response measurement of an eight-track reproducer, 6.3 mm (0.25 in.) tape, showing fringing error of 4 dB at 50 Hz with a full-track recording. **Solid curve:** full-track recording, spot frequencies. **Dashed curve:** one track only of eight recorded, spot frequencies. Data points are connected with assumed smooth curves.

MECHANICAL MISADJUSTMENT OF THE REPRODUCING HEAD

The gapped reproducing head is a "flux collector" which gathers the flux from the recorded track. Proper flux collection depends on having intimate contact and correct alignment between the recorded track and the gap area: any imperfection of this alignment or contact will result in losses at some or all frequencies. In principle, errors of contact and orientation can be corrected in the reproducing equalization. The practical problems are:

1. A system with faulty contact and/or alignment is usually unstable, i.e., the response is variable during the measurement, and from one measurement to another.

2. The usual equalizer is incapable of correcting for faulty contact and/or orientation, i.e., the range and shape of equalizer responses do not generally match the response of the system in which there are contact and/or orientation losses.

3. Although faulty contact and/or orientation reduces the signal and the tape noise by approximately the same amount, the head and amplifier noises remain constant, so that the signal-to-noise ratio is usually degraded.

Because of these reasons, the contact and orientation should be mechanically adjusted in order to prevent errors in respect to a number of variables.

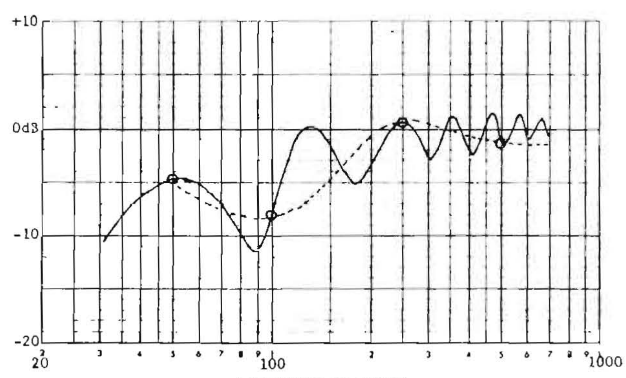

Fig. 5. Frequency response measurement of an eight-track reproducer, 6.3 mm (0.25 in.) tape, showing error of up to 7 dB due to measuring 4 points and assuming a smooth response between these points. One track of eight recorded. **Dashed curve:** assumed response from four spot frequencies. **Solid curve:** true response with sweep frequency.

Head Height

The height of the reproducing head should be adjusted accurately so that the reproducing head cores will coincide with the recorded tracks. This is particularly critical with narrow tracks (e.g., four- and eight-track systems). A misalignment of the reproducing head, causing the recorded test tape track to contact only a portion of the reproducing head core, will cause a reduction of the reproducing core flux at medium and short wavelengths, but, due to the fringing effect, not at long wavelengths. Thus one has both a level-setting error, and a frequency response error. Misadjustments of recording and reproducing heads may also cause recorded levels which are too high or too low, depending on the nature of the misalignment. Too high a recording level will in turn cause high distortion.

Head height errors escape detection when full-track test tapes are used with multiple-track reproducers.

Azimuth Angle

The gap of the reproducing head should be parallel to the gap of the recording head. Standard practice is to make both of these gaps perpendicular to the edge of the tape. These relationships will be affected by the azimuth and zenith adjustments, and the tape guiding.

Azimuth Adjustment.—Practical azimuth adjustment is made by reproducing the "azimuth adjustment" section of a reproducer test tape.[2] As the azimuth angle of the reproducing head is changed, the signal output will rise and fall, as shown in Fig. 6. The adjustment must

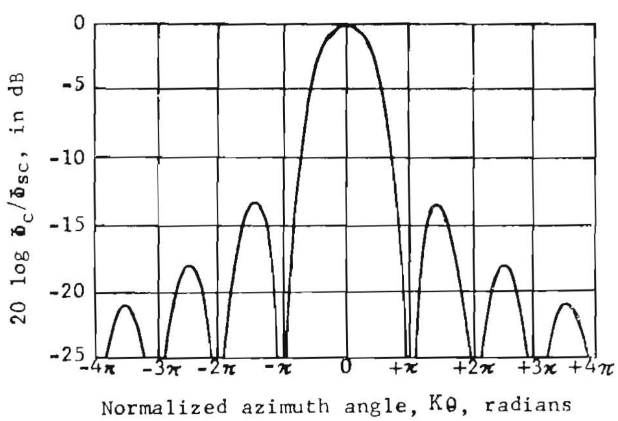

Fig. 6. Output vs azimuth angle, where θ = azimuth angle in radians, $K = \pi w/\lambda$, w = track width, λ = wavelength (in the same units), and $\Phi_c/\Phi_{sc} = (\sin K\theta)/K\theta$, for $\theta < 0.2$ radians (11°).

be made to the peak with the *maximum* output ($\theta = 0$). If, before adjusting the azimuth from the test tape, the reproducing head is visually adjusted so that the edge of the head is approximately parallel to the edge of the tape, the chances of setting to the wrong peak are greatly reduced.

Zenith Adjustment.—Proper guiding requires that all tape guides and the front faces of the heads be parallel to the axes of the tape reels. These, in turn, are usually perpendicular to the top plate. This adjustment of the heads is called the zenith adjustment—all axes should "point up". If any of these elements are not parallel, any change in tape tension[7] will cause the tape to "bow", producing an apparent azimuth change; since in this case the azimuth depends on the tension, unstable high-frequency response results. A simple technique will aid in setting the zenith adjustment:

1. Paint the face of the head with dye, using a red felt-tip marking pen. (Wax pencil may be used, but is messy; a layout fluid such as Dykem is also usable, but it takes too long to wear off.)
2. Play a piece of scrap tape until the dye is worn off the head face where the tape runs.
3. Observe the wear pattern of the dye on the head face. If the zenith adjustment is correct, the right and left edges of the wear pattern will be parallel; if they form a *V*, the zenith is incorrect.

Location of the Edge of the Tape.—Changes of position of the edge of the tape will also usually cause the tape to bow, resulting in the apparent azimuth changes mentioned above. If the tape guides are too wide, the tape edge will wander. If guides or heads have a slot worn in them, then different widths of tape will lie in them differently. This is especially noticeable if heads are re-adjusted after having been allowed to "wear in" in an incorrect adjustment.

Head-to-Tape Spacing (Poor Contact)

Response loss due to spacing between tape and head in reproducing is found from the formula: *loss* (in dB) $= 55\, s/\lambda$, where s is the tape-to-head space, and λ is the recorded wavelength. Very small spacings cause large losses: the slope is not "6 dB/octave", but exponential, i.e., the *slope* increases with frequency. Unintentional spacing may come from any of several sources, including:

Dirt on the Heads.—Material (usually loose tape oxide, or loose scraps of oxide and base material from the slitting process) may accumulate on the head face in use, causing spacing loss. Heads should be cleaned carefully before measurements and/or adjustments are performed.

Tape Tension Adjustment.—Tape-to-head force which causes tape-to-head contact is commonly obtained in professional recorders by having the heads deflect the tape path between two guides. In this case the force which holds the tape in contact with the head is proportional to the hold-back tension. Low contact force may therefore be caused by a hold-back tension that is too low because of improper adjustment, or because of the use of large reels[8] with the *Reel Size* (tension) switch set for small reels[9] (low tension). This low force again allows separation of head and tape.

Inadequate Wrap Angle.—In the design of a head assembly or in replacing heads in an adjustable head assembly, it is possible to have too little wrap of the tape around the heads. For a given tape tension, head-to-tape force is a function of the wrap angle; angles of less than about 12° total deflection of the tape at each head are unlikely to give adequate contact force for the elimination of the spacing loss.

Vertex Adjustment.—In the machines described above which obtain tape-to-head force by having the heads deflect the tape path between two guides, the *gap* of each head must be at the *vertex* of the angle so formed in order to have best tape-to-gap contact. This is shown in Fig. 7: misadjustment again causes spacing loss.

Worn Heads.—Mention was made earlier of guiding

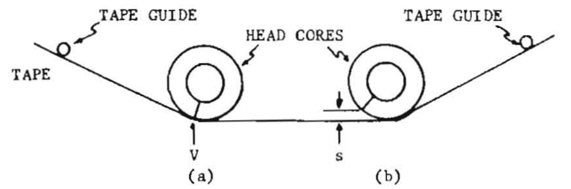

Fig. 7. Vertex adjustment. **a.** Gap of the head at the vertex of the tape wrap angle V with no spacing between gap and tape. **b.** Gap of the head not at the vertex of the tape wrap angle, resulting in spacing s.

Fig. 8. Cross-section of a worn head face, showing step-shaped pattern of the wear which lifts the tape out of intimate contact with the head face.

problems due to a head which has a slot worn in it. Such a slot causes a further difficulty: when a head wears, the cross-section is usually stepped, as shown in Fig. 8. The steps often cause the edge of the tape to be lifted out of contact with the head face, with the resultant spacing loss.

CONCLUSION

Although the reproducer test tape provides the most satisfactory means known for measuring and adjusting the azimuth and frequency response of tape reproducers, there are numerous opportunities for making errors in the measurements. If care is taken in performing the measurements and these errors are avoided, measurements with a test tape should give accurate indications of the frequency response of a reproducer.

NOTES

1. John G. McKnight, "Absolute Flux and Frequency Response Characteristics in Magnetic Sound Recording: Measurements, Definitions and Standardization", J. Audio Eng. Soc. 15, 254 (July, 1967).
2. Robert K. Morrison, "Reproducer Test Tapes: Evolution and Manufacture", *J. Audio Eng. Soc.* 15, 157 (Apr., 1967). Reprint p. 1.
3. All standards referred to in this paper are fully described in: J. G. McKnight, "A List of Published Standards Related to Magnetic Sound Recording", J. Audio Eng. Soc. 15, 314 (July, 1967).
4. Several 2-, 4-, and 8-track reproducer test tapes are now available from Ampex: see the revised catalog at the end of this booklet.
5. K. Fritzsch, "Zur Wiedergabe grosser Wellenlaengen vom Magnetband" (The Reproduction of Long Wavelengths on Magnetic Tape). *Hochfrequenztechnik und Elektroakustik* 75, 39 (April, 1966). Fig. 2 is taken from Fritzsch's Fig. 14a. (Trans. to be published).
6. W. K. Westmijze, "Studies on Magnetic Recording", *Philips Research Reports* 8, 148; 161; 245; 343 (1953), and Reprints R213, R214, R217, R222. Fig. 3 follows Westmijze's function $S(\pi l/\lambda)$.
7. In most professional tape transports, the tape tension comes from a constant torque supply-reel motor. Therefore the tension is inversely proportional to the diameter of the supply-reel pack. The outside-to-inside tension ratio is 2:1 to 3:1, depending on style of reel.
8. Defined as NAB Type A reels, with 27 cm (10.5 in.) diameter.
9. Defined as NAB Type B reels with 18 cm (7 in.) diameter.

APPENDIX

Calibration Method for Making Long-Wavelength (Low-Frequency) Reproducer Test Tapes

At long wavelengths* the flux is constant **vs** wavelength for a constant recording field, which is in turn produced by a constant recording current. Therefore, to produce a **long-wavelength only** reproducer test tape requires only making the recording head signal current a known response **vs** frequency.† To measure the recording head current **vs** frequency, remove the high frequency recording bias current, e.g., by unplugging the bias oscillator tube or disconnecting the oscillator power. Sense the recording head signal current by means of a current probe attached around the lead of the recording head or by inserting a resistor in series with the ground side of the recording head, and measuring the voltage across this resistor. Measure the frequency response from amplifier input terminals to recording head current. Then one can compensate the input signal for this response, so as to produce the desired head current **vs** frequency when the recording is made.

If the test tape is for use with the NAB Standard, the low-frequency flux response should rise at 6 dB/octave with a transition frequency (+3 dB point) at 50 Hz. Such a test tape should be made at reduced level to prevent over-recording and consequent distortion at the lowest frequencies, since the equalized recording current is +8.6 dB at 20 Hz re/700 Hz.

For a test tape to the CCIR Standards or for many experimental purposes, constant current **vs** frequency is used with no low-frequency boost.

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* The wavelength λ should be much greater than the coating thickness t. Since $t \cong 12\ \mu m$ (0.5 mil), λ should be greater than about $500\ \mu m = 20$ mil. Therefore frequency should be 750 Hz or less at 38 cm/sec (15 ips).

† There are "secondary gaps" at the corners of a head core. If a recording head is used which has rectangular corners contacting the tape, additional long-wavelength recording response effects could occur. A ring head whose pole face gradually sweeps away from the tape does not seem to produce any such effect.

THE AUTHOR

John G. McKnight was born in Seattle, Washington, in 1931 and received his B.S. degree in electrical engineering from Stanford University in 1952. He has been with Ampex Corp. since 1953. In 1959 Mr. McKnight became manager of the advanced audio section of the Professional Audio Division at Ampex. He is presently staff engineer with the Consumer and Education Products Division of the company in Los Gatos, Ca. His work has included research and engineering on the dynamics of tape transports, magnetic recording—especially the recording of music—and tape recording standardization. He has presented and published many papers on magnetic recording.

Mr. McKnight is a member of several standards committees on magnetic sound recording. He is a senior member of the Institute of Electrical and Electronic Engineers and a member of the IEEE **Transactions on Audio** editorial board. He is also a Fellow of the Audio Engineering Society, an ex-governor and a member of the **Journal**'s editorial board.

AMPEX

TEST TAPES

AMPEX CORPORATION
PROFESSIONAL AUDIO PRODUCTS

PRELIMINARY REVISED CATALOG, JAN. 1968.

Ampex Test Tapes are the standard of the recording and broadcasting industries, and are used by development laboratories, service depots, recording and broadcasting studios throughout the world. All are recorded on the finest Ampex mastering equipment by skilled engineers working under laboratory conditions.

All signal information on Ampex Test Tapes is an original recording--not a duplication. This procedure holds all deviations from standard to an absolute minimum and assures maximum uniformity from one tape to another.

Ampex Test Tapes are made to agree with the equalizations given in the published standards of appropriate technical organizations (NAB, CCIR, IEC, RIAA, EIA, DIN).

All Ampex Test Tapes are referenced to the Standard Ampex Operating Level. This is the flux level at reference frequency, corresponding to (200 $\pm$10) nWb/m. This flux level was originally derived from a recording at 1% distortion measured on a representative piece of tape in 1949. This flux level (rather than the distortion) has been carefully controlled for over 19 years and remains the industry accepted standard in the U.S.A.

STANDARD REPRODUCER ALIGNMENT TEST TAPES

Application Recommended by AMPEX	Speed, in/s	Standards Using This Flux vs. Frequency (Note 1)	Equalization		Width, in.	Tracks (Note 2)	Catalog No.	Prof'l User Price, $ U.S.
			Transition Frequencies, Hz	(Time Constants, µs)				
For Use in U.S.A.	3.75	Ampex (1959); EIA (1959); DIN (1962).	50/1300	(3180/120)	1/4	FT	31331-01	21.95
	3.75	NAB (1965); RIAA (1965); IEC (1966 Proposal).	50/1800	(3180/90)	--	--	Special Order	--
	7.5	Ampex (1951); NAB (1965); RIAA (1965); EIA (1963); DIN home (1966).	50/3200	(3180/50)	1/4	FT	31321-01	21.95
					1/4	2T	4690010-01	21.95
					1/4	4T	31321-04	21.95
					1/2	FT	31321-05	35.00
					1	8T	4690007-01	150.00
	15	Ampex (1949); NAB (1953 & 1965); EIA (1963).	50/3200	(3180/50)	1/4	FT	31311-01	21.95
					1/4	2T	4690009-01	21.95
					1/2	FT	31311-05	35.00
					1	FT	4690005-01	150.00
					1	8T	4690006-01	150.00
For International and Foreign Use.	3.75	IEC (1964).	50/1100	(3180/140)	--	--	Spcl. Order	--
	7.5	CCIR (1966); IEC (1964); DIN studio (1966).	0/2300	(∞/70)	1/4	FT	4690014-01	21.95
					1/2	FT	4690015-01	35.00
	15	CCIR (1953 & 1966); IEC (1962); DIN (1962).	0/4600	(∞/35)	1/4	FT	31313-01	21.95
					1/2	FT	31313-05	35.00
For Special Purpose Use.	15	Ampex Mastering Equalization.	Special		1/4	FT	31312-01	21.95
					1/2	FT	31312-05	35.00
	60	3200 Duplicator Setup.	Special		1/4	FT	6878	40.00
Not Recommended - Obsolete	3.75	Ampex (previous to 1959).	50/800	(3180/200)	1/4	FT	31334-01	21.95
	7.5	CCIR (1963 & before); IEC (1962 & before); DIN (1962 & before).	0/1600	(∞/100)	1/4	FT	31323-01	21.95
					1/2	FT	31323-05	35.00

Note 1: Only the equalizations of the Ampex Test Tapes correspond to these standards--levels, frequencies, durations, etc., do not necessarily correspond.

Note 2: FT = Full track; 2T = both tracks of two track format; 4T = tracks one and three only of four track format; 8T = all eight tracks of eight track format.

FLUTTER TEST TAPES

Application Recommended by AMPEX	Speed, in/s	Frequency, Hz	Playing time, minutes	Recorded Flutter less than, % rms (0.2-200 Hz band)	Width, in.	Tracks	Catalog No.	Prof'l User Price,$ U.S.
Most U.S.A. & Other Flutter Meters.	3.75	3 000	30	0.03	1/4	FT	31336-01	21.95
	7.5	3 000	15	0.03	1/4	FT	31326-01	21.95
	15	3 000	7.5	0.03	1/4	FT	31316-01	21.95
New German & Some Other Meters Using "Preferred Frequency"* of 3 150 Hz.	3.75	3 150	30	0.03	1/4	FT	4690013-01	21.95
	7.5	3 150	15	0.03	1/4	FT	4690012-01	21.95
	15	3 150	7.5	0.03	1/4	FT	4690011-01	21.95

* U.S.A. Standard S1.6-1967, ISO R 266-1962; "Preferred Frequencies for Acoustical Measurements".

TEST TAPE CONTENTS, USES AND COMMENTS

The Ampex Reproducer Test Tapes consist of two sections: a Frequency Response Section, and an Ampex Operating Level Section. The individual sections are identified by announcements. The Frequency Response Section is used for the practical calibration of the frequency response of magnetic tape reproducers: when the reproducer flux-frequency response conforms to the standard to which the Test Tape is recorded, the reproducer output voltage is constant versus frequency. The Ampex Operating Level Section is used to set the reproducer gain on professional recorders with a vu meter so that it indicates its reference deflection (the point marked "0 vu" or "100%").

1. All 3.75 in/s tapes contain the following frequencies in Hz, recorded 10 dl below Ampex Operating Level for 10 s each, except as otherwise shown:

   500 (15 s) / 7 500 (30 s) / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50; reference frequency at Ampex Operating Level, 500 Hz for 15 s.

2. All 1/4 and 1/2 inch 7.5 in/s tapes contain the following frequencies in Hz, recorded 10 dl below Ampex Operating Level for 10 s each, except as otherwise shown:

   3 000 Hz (60 s)* / 700 (15 s) / 15 000 (30 s) 12 000 / 10 000 / 7 500 / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50; reference frequency at Ampex Operating Level, 700 Hz for 15 s. One inch Test Tapes are identical except that all of the durations are doubled.

   * Only on 31321-04; for vertical head adjustment.

3. All 1/4 and 1/2 inch 15 in/s tapes contain the following frequencies in Hz, recorded at operating level, for 10 s each except as otherwise shown: reference frequency, 700 (15 s) / 15 000 (30 s) / 12 000 / 10 000 / 7 500 / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50 / 30. One-inch Test Tapes are identical except that all of the durations are doubled.

FLUTTER TEST TAPES

These tapes are used for measuring the flutter of reproducers in accordance with USA and NAB Standards. The tape lengths are 600 ft.

The use of these Test Tapes avoids the problem which occurs with a "record-rewind-reproduce" measurement (USASI "non-standard method"; DIN Standard); namely, that when the same transport is used both for recording and reproducing, the flutter from recording will alternately cancel and reinforce the flutter from reproducing. Therefore multiple measurements are necessary to find the true flutter value if the Test Tape is not used.

Most USA flutter meters now use the 3 000 Hz frequency; the new "Preferred Frequency" of 3150 Hz is used in new German flutter meters, and will become more common in the USA in the future.

FLUTTER TEST TAPES

Application Recommended by AMPEX	Speed, in/s	Frequency, Hz	Playing time, minutes	Recorded Flutter less than, % rms (0.2-200 Hz band)	Width, in.	Tracks	Catalog No.	Prof'l User Price,$ U.S.
Most U.S.A. & Other Flutter Meters.	3.75	3 000	30	0.03	1/4	FT	31336-01	21.95
	7.5	3 000	15	0.03	1/4	FT	31326-01	21.95
	15	3 000	7.5	0.03	1/4	FT	31316-01	21.95
New German & Some Other Meters Using "Preferred Frequency"* of 3 150 Hz.	3.75	3 150	30	0.03	1/4	FT	4690013-01	21.95
	7.5	3 150	15	0.03	1/4	FT	4690012-01	21.95
	15	3 150	7.5	0.03	1/4	FT	4690011-01	21.95

* U.S.A. Standard S1.6-1967, ISO R 266-1962; "Preferred Frequencies for Acoustical Measurements".

TEST TAPE CONTENTS, USES AND COMMENTS

The Ampex Reproducer Test Tapes consist of two sections: a Frequency Response Section, and an Ampex Operating Level Section. The individual sections are identified by announcements. The Frequency Response Section is used for the practical calibration of the frequency response of magnetic tape reproducers: when the reproducer flux-frequency response conforms to the standard to which the Test Tape is recorded, the reproducer output voltage is constant versus frequency. The Ampex Operating Level Section is used to set the reproducer gain on professional recorders with a vu meter so that it indicates its reference deflection (the point marked "0 vu" or "100%").

1. All 3.75 in/s tapes contain the following frequencies in Hz, recorded 10 dl below Ampex Operating Level for 10 s each, except as otherwise shown:

   500 (15 s) / 7 500 (30 s) / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50; reference frequency at Ampex Operating Level, 500 Hz for 15 s.

2. All 1/4 and 1/2 inch 7.5 in/s tapes contain the following frequencies in Hz, recorded 10 dl below Ampex Operating Level for 10 s each, except as otherwise shown:

   3 000 Hz (60 s)* / 700 (15 s) / 15 000 (30 s) 12 000 / 10 000 / 7 500 / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50; reference frequency at Ampex Operating Level, 700 Hz for 15 s. One inch Test Tapes are identical except that all of the durations are doubled.

   * Only on 31321-04; for vertical head adjustment.

3. All 1/4 and 1/2 inch 15 in/s tapes contain the following frequencies in Hz, recorded at operating level, for 10 s each except as otherwise shown: reference frequency, 700 (15 s) / 15 000 (30 s) / 12 000 / 10 000 / 7 500 / 5 000 / 2 500 / 1 000 / 500 / 250 / 100 / 50 / 30. One-inch Test Tapes are identical except that all of the durations are doubled.

FLUTTER TEST TAPES

These tapes are used for measuring the flutter of reproducers in accordance with USA and NAB Standards. The tape lengths are 600 ft.

The use of these Test Tapes avoids the problem which occurs with a "record-rewind-reproduce" measurement (USASI "non-standard method"; DIN Standard); namely, that when the same transport is used both for recording and reproducing, the flutter from recording will alternately cancel and reinforce the flutter from reproducing. Therefore multiple measurements are necessary to find the true flutter value if the Test Tape is not used.

Most USA flutter meters now use the 3 000 Hz frequency; the new "Preferred Frequency" of 3150 Hz is used in new German flutter meters, and will become more common in the USA in the future.

Sound Talk®

A Technical Service to the Industry from the makers of Scotch Magnetic Tape

VOL. II
No. 3
1969

ALIGNMENT

Since the design of the first tape recorder and the use of magnetic recording tape, the equipment and tape have continuously undergone improvements. Some of the improvements have allowed greater fidelity, better signal-to-noise ratio, excellent reliability and service life. These improvements have also reduced distortion, crosstalk between channels and high frequency (short wavelength) losses.

All of the aforementioned benefits are the result of better machine electronics and also better mechanical drive and guiding systems. Ironically, the advanced electronics, which record and play back the program material, are at the mercy of the mechanical drive and guide systems which move the tape across the head to assure proper head-to-tape contact. Therefore, correct guiding, intimate head-to-tape contact and head alignment are prerequisites for maximum recorder performance, especially when using multi-track or professional type wide-width (½" to 2") tape equipment.

This issue of SOUND TALK will discuss the various elements which are involved in guiding a tape across the deck. Because of the variety of recorders available, guiding and alignment will be discussed in terms of basic principles only; and those adjustments which are deemed necessary should be performed by a qualified technician familiar with the individual machine manufacturer's specifications.

Oftentimes problems with recorder operation or performance degradation are blamed on what appears to be faulty heads or poor tape when, in reality, the problem is actually caused by a misaligned head or improper tape guiding. These problems can occur in any machine, regardless of quality or age. The situation of guiding and alignment is so critical that major recording and duplicating studios make it a practice to systematically check their decks for these parameters to assure proper operation.

To assure that the tape moves across the deck in the proper manner and ultimately crosses the head correctly, it is necessary to establish the correct tape path from the supply reel through the guide system to the heads and back to the take-up reel. Once the correct path is established it is usually quite simple to maintain this condition.

TAPE PATH CENTERLINE

The centerline of each component which is in direct contact with the tape should maintain an unvarying reference plane (Figure 1). The edge clearance limits of these guiding components are within a few thousandths of the prescribed maximum tape widths; therefore, any slight variation from the true centerline reference can cause bending of the tape edges. Additional effects could be tape skewing on a tangent from its path, azimuth misalignment and excessive friction. True centerline tracking is particularly important when using wide tape widths (½" to 2") because wider tapes exhibit greater resistance to longitudinal changes or "steering." Wide recording tape exhibits a tendency to curl or roll along its edges when subjected to the steering action of inaccurate centerline tracking.

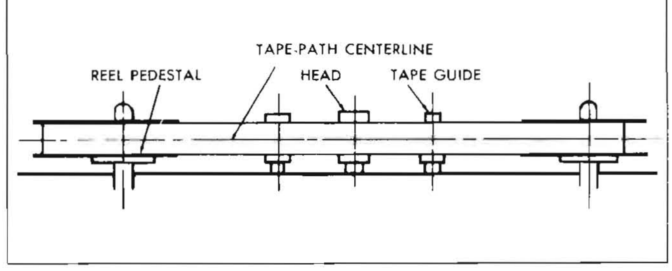


FIGURE 1. SIMPLIFIED TAPE PATH CENTERLINE

PEDESTAL HEIGHT AND ANGLE

Tram error and tape edge damage may occur from improperly positioned tape reel pedestals. A slight variation of the pedestal axis from a true right angle to the tape path creates an exaggerated error at the reel flange circumference (Figure 2).

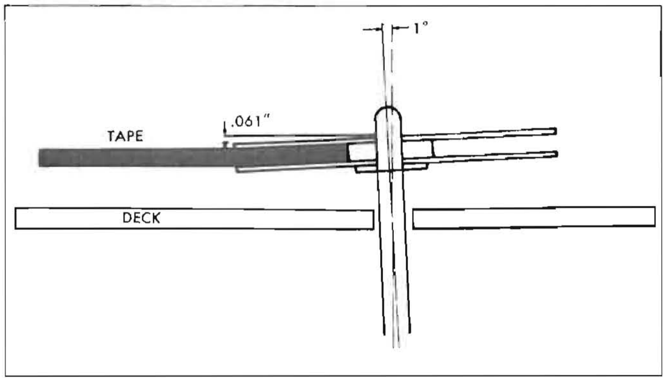


FIGURE 2. IMPROPER PEDESTAL POSITION

A pedestal with an angular error of just one degree will displace the edge of a 7 inch reel flange by 61 mils from the proper horizontal position. If the pedestal height adjustment is incorrect and compounded with an erroneous angle, the total error is cumulative; for example, with an angular displacement of 0.061" and improper height of 0.030" the total error reflected to the tape path is 0.091" – nearly 1/10th of an inch. This type of irregularity will create guiding problems throughout the tape path and can cause the tape to rub along the edge of the reel, creating edge damage (Figure 3).

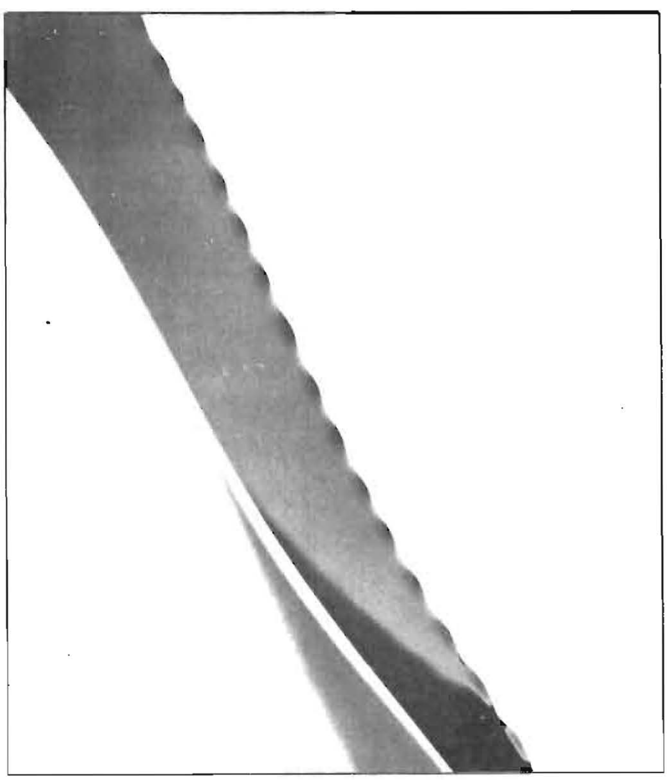


FIGURE 3. SINGLE STRAND OF TAPE SHOWING SEVERE EDGE DAMAGE

The type of edge damage shown in figure 3 may also be caused by a damaged reel. If the reel flanges are bent or warped so that the normal clearance between the tape and the flange is reduced, the tape can scrape against the flanges.

When determining proper pedestal height, differences between the flange thickness of plastic and metal reels must be taken into account. Plastic reels have thicker flanges than metal reels to provide the needed strength. If both metal and plastic reels are used, the centerline reference should be established using a plastic reel. Although this will cause the tape to wind slightly above the center on the metal reel (the thinner flanges will cause it to rest slightly lower on the pedestal), the thinner flanges also provide greater clearance which compensates for the difference in tape wind. When adjusting pedestal height in reference to the tape centerline, it is important to determine the dimensions of the reels normally being used. The Electronic Industries Association (EIA) has suggested basic reel sizes and dimensions in its Standard RS 254A, which specifies a nominal reel width of 0.462" for ¼" reels (nominal tape width plus 0.212"). Other reel widths follow the same standard (½" reel width is 0.500" plus 0.212" = 0.712"). The specified dimensions are standard for the precision reel, which is carefully manufactured to assure concentricity of the hub and flanges, accurate flange run-out and consistent separation distance between flanges. If a precision reel is unavailable or impractical to use (normally available in only 10½" or larger sizes), the dimensions established may be applied to the reel being used to check the transport (see calculations in figure 4).

For ¼-inch Precision Reels:

$$W_F = \frac{W_R}{2} - \left(\frac{W_T}{2} + W_C\right)$$

$$W_F = \frac{.462}{2} - \left(\frac{.246}{2} + .005\right)$$

$$W_F = .103\text{-inch}^{\bullet}$$

where . . .

W_F = distance between pedestal and nearest flange inner face

W_R = .462-inch average or nominal overall reel width within the lateral mounting area

W_T = average tape width

W_C = desired clearance between each tape edge and adjacent flange

To Then Determine Pedestal Height:

$$H_P = X - (W_C + W_F)$$

$$H_P = X - (.005 + .103)$$

$$H_P = X - .108\text{-inch}$$

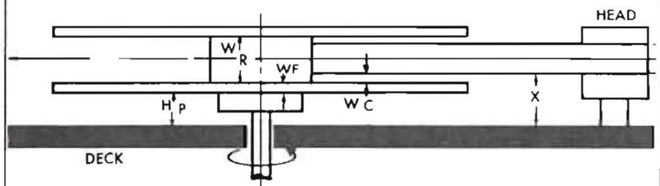
where . . .

H_P = height of pedestal from reference plane

X = distance from reference plane (deck) to nearest tape edge correctly positioned with respect to guides and heads

FIGURE 4. PEDESTAL HEIGHT AND TAPE PATH DIMENSIONS

°For other (½, ¾, 1, 1¼, 1½, 1¾, and 2") precision reels it can be easily shown that W_F = .102-inch. This is because average tape widths for these reels are .002 rather than .004 inch less than the appropriate multiple of ¼-inch. (e.g., average width for ½-inch tape is .498, for 1-inch tape, .998, etc.).



Dimensions important to tape-path centerline and pedestal adjustments.

FIGURE 4. PEDESTAL HEIGHT & TAPE PATH DIMENSIONS (CONT.)

Because tape reels are symmetrical, a perfect wind on a correctly adjusted transport would center the tape equally between the flanges. When establishing the centerline, some type of reference must be used. Generally the mounting plate or deck is adequate for measuring the tape position through the entire tape path. By establishing a reference measuring method, such as "X" in figure 4, any deviations in the tape path created by the pedestals, capstan and idlers, or guides can be easily discovered. The intricate calculations shown in figure 4 provide the basic dimensions for establishing pedestal height and tape centerline.

GUIDING

As the tape moves across the deck, its path is determined by a series of guides. The guides may be fixed, roller type, or mounted on tape tensioning devices. Fixed guides, because of the direct mounting, generally will not become misaligned. Fixed guides can create edge damage problems, such as shown in figure 3, if they become worn or damaged.

Movable guides, especially those mounted on tension compensating arms, are vulnerable to misalignment because of bent arms. During tape centerline measurements, be sure to check the perpendicular attitude of the guide with reference to the deck surface throughout its entire operational arc. Precise measurement of the tape path entrance into the guide and the tape exit path will determine proper alignment. Careful visual inspection (with a magnifying glass) of the tape passage through the guide will determine if the tape is being subjected to any excessive edge pressure which may cause curling or bending along the edge of the tape.

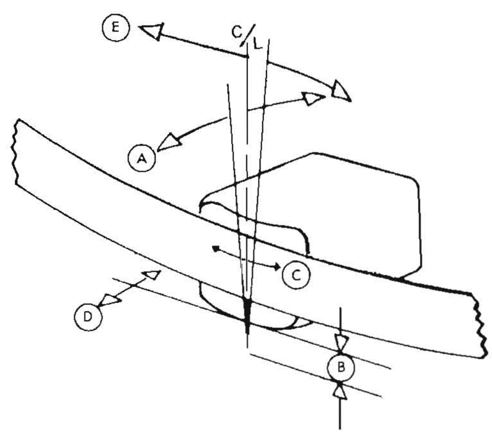
Roller guides, drive capstans and idler wheels can also create guiding problems. Any misalignment or uneven wear on these components may cause the tape to deviate from the ideal centerline. A capstan or idler wheel which not truly perpendicular to the established centerline or is worn into a tapered shape will cause the tape to travel in an improper path, following the component's angular deviation from perpendicularity.

All of the preceding considerations are intended to assure an even and smooth tape passage throughout the entire path. Proper tape movement across the deck is essential for correct head-to-tape interface. The intimate relationship between the recording tape and the recorder head or heads is the final parameter which must be explored to assure proper operation.

HEAD ALIGNMENT

In magnetic recorders, the high frequency response and inter-channel crosstalk are extremely dependent on head alignment. In most tape transports the heads are adjustable and can be aligned as required to establish the correct head-to-tape interface. The adjustment is very precise and is best accomplished by a factory qualified technician referring to the manufacturer's service manuals. There are five basic adjustments involved in correctly positioning a recorder head, as shown in figure 5. Two of these positioning adjustments (A and B, Figure 5) are concerned with the tape centerline.

HEAD ALIGNMENT — Includes all mechanical adjustments necessary to assure proper coincidence of head gap with tape, or more specifically, a properly recorded tape track.



A) Tilt, in which the face of the head must be simultaneously tangent to the same degree with both edges of the tape and without distortion of either of the latter.
B) Height, in which the gap width dimension is centered on the standard track location.
C) Tangency assures that the tape contacts the portion of the head face containing the head gap.
D) Contact, head position into or away from the tape to assure proper contact pressure between head and tape ("wrap"). Not as critical with machines employing pressure pads at the heads.
E) Azimuth or skew, in which width dimension (corresponds to track width) of gap is exactly 90° with tape edge.

FIGURE 5. HEAD ADJUSTMENT PLANES

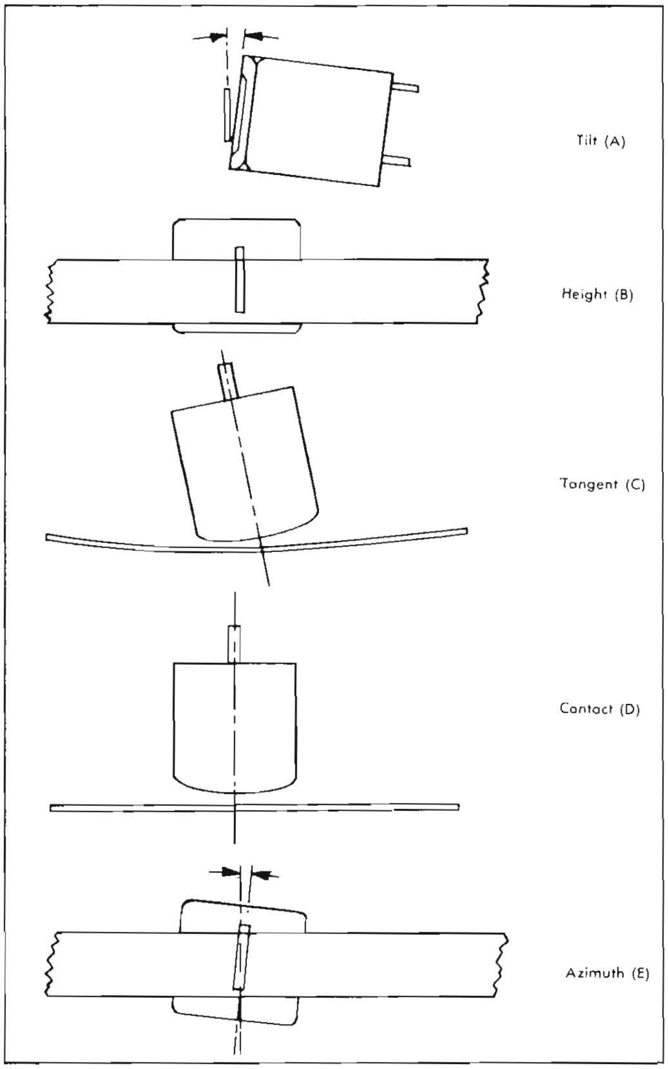


FIGURE 5. HEAD ADJUSTMENT PLANES (CONT.)

TILT

The first basic head adjustment is to establish a true vertical position for the face of the head (Arc A – Fig. 5) with reference to its contact with the tape. The correct attitude is one in which the head neither tilts into nor away from the tape surface. Establishing the correct vertical attitude is important to maintain uniform tension across the entire width of the tape in contact with the head. If the tape is under more tension at one edge than at the other, total intimate contact between the tape and head will be disturbed. The difference in tension can also cause the tape to skew away from the centerline.

HEIGHT

The next basic head adjustment, within the centerline reference, is head height (B – Fig. 5). Improper head height is manifested as mistracking or crosstalk. On multiple track recordings this particular adjustment is very critical in that loss of output, noise and inter-channel crosstalk can result if the playback head gap is not perfectly tracking the recorded path on the tape. If recording with a head maladjusted in height, it may be virtually impossible to play the tape back on another machine.

While checking head height, inspect the face of the head for wear. As the head wears, an indentation is formed along the tape path which actually becomes a tape guide (Figure 6). If the head position or tape path is changed, the worn area will no longer coincide with the tape edge. This will cause tape damage. If a severely worn head is discovered, replacement is recommended.

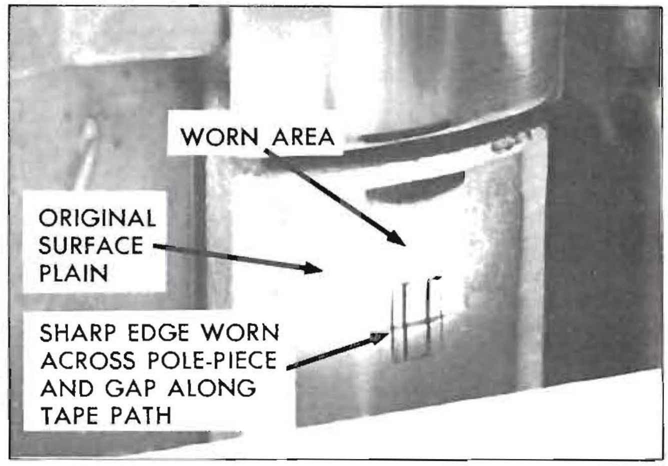


FIGURE 6. EXAMPLE OF IMPROPERLY POSITIONED HEAD EXHIBITING WEAR PATTERN

TANGENCY

Once the tape centerline path across the head is established, the head-to-tape interface must be checked. Tangency (Arc C – Fig. 5) is simply the squaring of the record and playback gaps to the tape's surface. Correct tangency is important to assure proper head-to-tape contact at the head gaps. If the tape contact is not correct, high frequency response will suffer and, more important, the system may become oversensitive to dropouts. Dropouts are usually caused by debris or contamination which separate the tape's oxide surface from the head gaps. Needless to say, any interruption of head-to-tape contact will result in a degraded signal output; and if the separation is severe, a complete signal loss may result.

CONTACT

Contact (D – Fig. 5) is the head position in respect to the tape wrap. Correct head-to-tape contact is assured by the slight bending or "wrap" in the tape path as it passes over the head. Insufficient contact can result in poor high frequency response and oversensitivity to dropouts, as previously mentioned.

Many recorders are equipped with pressure pads which force the tape against the head by applying pressure to the tape's backing adjacent to the head. When inspecting the head position, the pressure pads must be checked for signs of wear or damage. The pad can become worn, developing a channel which corresponds to the tape

path. If the pad is deeply worn, head-to-tape contact can be reduced, which will affect high frequency response. Because of the intimate contact between the pad and the tape's backing, surface contamination will tend to stick to the pad. Contamination deposits and build-up on the pressure pad may create hard spots and form an uneven contact surface which can produce "squeal," loss of head-to-tape contact and cause excessive tape wear. If the pressure pad is worn or contaminated, it should be replaced. During pad replacement, care must be taken to assure proper pad size, installation and correct positioning.

A most important head adjustment is that of azimuth (Arc E – Fig. 5). If the reproducing gap (playback head) is not parallel to the recorded poles on the tape, serious loss of high frequency (short wavelength) response will result, as shown in figure 7.

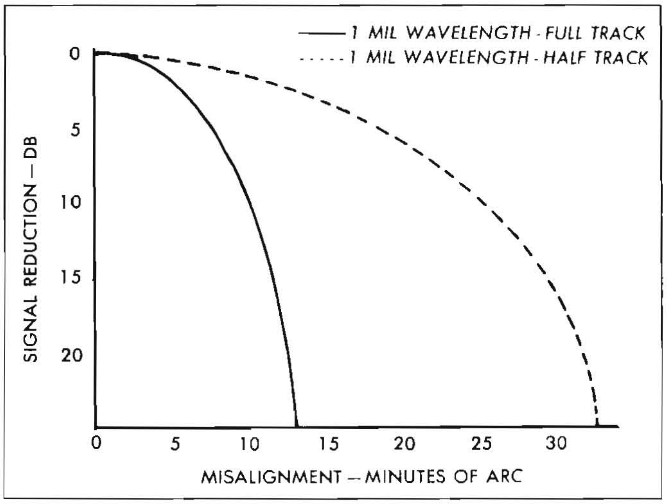


FIGURE 7. HIGH FREQUENCY LOSSES DUE TO HEAD MISALIGNMENT

AZIMUTH

To assure compatibility and interchangeability, it is quite important that record and playback heads are adjusted so the gaps are exactly perpendicular to the tape path centerline. Since it is very difficult to establish true vertical reference with a head because of the extremely small gaps in the pole piece, the azimuth adjustment is best determined by using a special pre-recorded alignment test tape. The alignment test tape has a carefully recorded high frequency signal which, when played back, is used to determine output level. Because of the high frequency dependency on head alignment, any misalignment is readily apparent in the loss of output, as shown in figure 7.

When using an alignment tape to check azimuth, a variety of methods can be employed, the simplest being to deliberately skew the tape across the head while checking output. If the output, as indicated by the signal level meter (or the playback volume), is highest with normal tape alignment across the head, it can be assumed that azimuth is correct. If the output signal level increases while deliberately skewing the tape, it can be assumed that the head azimuth is incorrect and should be re-adjusted. The head should then be realigned to yield maximum or peak output. In the case of separate record-playback heads, the playback head should be peaked per the output signal level determined while using the pre-recorded alignment tape. The record head azimuth should then be peaked while recording on a blank tape and playing back through the correctly positioned playback head. Only a studio prepared pre-recorded tape should be used for an azimuth test.

While checking head azimuth it is also good practice to inspect the pressure pad (if used) for wear. If a pad which has become worn does not properly position itself against the tape, it will have a tendency to skew the tape out of alignment with the head gap, giving the same effect as incorrect head azimuth. If the pressure pad shows signs of a wear-created channel, it should be replaced.

SUMMARY

The improvements in recorder design, electronics and magnetic recording tape have contributed to a media which provides excellent frequency response, low distortion and virtually perfect reproduction of recorded material. The benefits of these improvements are limited to the component condition and the adjustments of each individual machine. By periodically cleaning and inspecting your recorder to verify that the tape path is properly established by the reels and guiding system and that the interface between head and tape is correct, maximum recorder performance can be assured.

If at any time you have specific questions about this topic, simply write to:

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LETTERS TO THE EDITOR

MEASURING A TAPE REPRODUCER WITH IEC-RESPONSE, USING AN NAB-RESPONSE TEST TAPE

JOHN G. MCKNIGHT

Ampex Stereo Tape Division, Los Gatos, California

Recording companies in the USA frequently receive recordings from European and other foreign companies which are recorded with the IEC[1] (CCIR[2]) flux-frequency responses. Test tapes are available in the USA (from Ampex, for instance) for the IEC flux-frequency response, and these test tapes should be used for adjust-

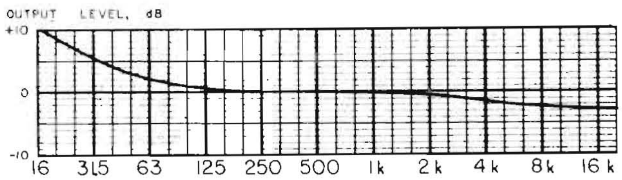

Fig. 1. Output level vs frequency of a properly adjusted IEC 38 (15 in/s) reproducer when reproducing an NAB 38 (15 in/s) test tape. (Transition frequencies are 50 Hz and 3150 Hz for NAB 38; 0 Hz and 4500 Hz for IEC 38.)

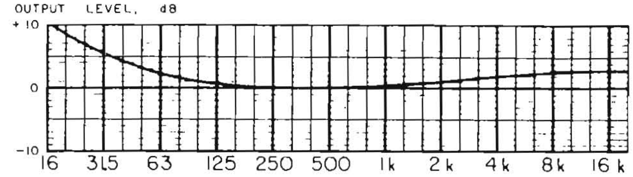

Fig. 2. Output level vs frequency of a properly adjusted IEC 19 (7.5 in/s) reproducer when reproducing an NAB 19 (7.5 in/s) test tape. (Transition frequencies are 50 Hz and 3150 Hz for NAB 19; 0 Hz and 2240 Hz for IEC 19.)

ing IEC-response reproducers. Sometimes, however, a USA company will have the NAB-response[3] test tapes, but no IEC-response test tapes. The question naturally arises: "What should the output level vs. frequency be for a reproducer when it is properly adjusted for the IEC response, but tested with an NAB-response test tape?"

Although this response difference could be derived from the published curves[4], the author has here recalculated the responses, taken the differences, and plotted the resulting curves. Figs. 1 and 2 show the output vs. frequency of a properly adjusted IEC reproducer when reproducing an NAB test tape, for 38 cm/s (15 in/s) and 19 cm/s (7.5 in/s), the two common speeds for professional exchange of program material. The inverse of these curves could of course be used by anyone having the IEC-response test tapes, and wishing to know the output level vs. frequency of a reproducer adjusted for NAB response.

[1] "Magnetic tape recording and reproducing systems: Dimensions and characteristics" International Electrotechnical Commission, IEC Recommendations, Publication 94, Third edition, 1968. (Standards for recordings for the professional exchange of programs are given by IEC).

[2] "Standards of sound recording for the international exchange of programs: Single-track recording on magnetic tape", International Radio Consultative Committee (CCIR), Recommendation 261-1 (1966). "Standards of sound recording for the international exchange of programs: Two-track stereophonic recording on magnetic tape", CCIR Recommendation 408-1 (1966). These will be found on pages 13-15 and 23-24 respectively of *Documents of the XIth plenary assembly of the CCIR*, Vol. V (Broadcasting and Television) (Oslo, 1966). (These recommendations are specifically for the international exchange of *sound broadcast* programs. Because the CCIR recommendations were established before those of the IEC, European recording studios first used the CCIR Recommendation and often still refer incorrectly to the recommendations of CCIR rather than IEC. The flux-frequency responses given by IEC in 1968 are identical to those given by CCIR in 1966.)

[3] "Magnetic tape recording and reproducing (reel-to-reel)", (USA) National Association of Broadcasters, April 1965. (Since no USA Standard exists for professional sound recording, the NAB Standard is commonly used in the USA.)

[4] J. G. McKnight, "Flux and flux-frequency measurements and standardization in magnetic recording", *J. SMPTE 78*, pp. 457-472 (June 1969). See Table III and Fig. 9.

Speed, Pitch and Timing Errors in Tape Recording and Reproducing*

JOHN G. McKNIGHT

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Because tape is a plastic medium driven by a capstan in a complicated rolling process, an accurate specification of "tape speed" is not simple. However, it is shown that even a complete specification of tape speed alone is not adequate to specify the pitch and timing error because changes of the recorded wavelength due to tape length changes cause additional independent timing and pitch errors of up to 1.0%. These are significant in comparison with the NAB tape speed tolerance of ±0.2%. Measurement techniques are also reviewed.

INTRODUCTION Recording and reproducing system specifications usually include a value for "speed error". It is one purpose of the present paper to show that speed error is not really of primary interest—rather one is actually interested in "timing error" and "pitch error". Timing error is the amount by which the duration of a reproduced program differs from the duration of the original program; this is of primary interest in broadcasting operations, where very accurate timing is demanded. Pitch error, on the other hand, is the amount by which the pitch of a reproduced program differs from the pitch of the original program. This is of primary interest in recordings of music which are to be spliced together: a small constant pitch error is not easily detected by the average listener, but when a splice juxtaposes sections recorded with different pitch errors, a sudden change of pitch occurs which is very obvious and disturbing. Although either error can be calculated from a complete knowledge of the other, for practical purposes we will consider them as two separate effects.

In practice, the errors of a *given* system are often identical in recording and in reproducing, so that its own errors in recording are cancelled out in reproducing. Operationally, this should be considered as a special case, since a record is more usually reproduced on a *different* transport from that used to make the recording. Therefore, when recording is discussed, reproduction on a "perfect" reproducer will be assumed, and vice versa.

In a disc system, the medium moves at exactly the speed of the turntable on which it lies, and the recording cannot change its physical length. Similarly, in a perforated film system, the medium moves at exactly the speed of the sprocket which drives it, and the recording cannot change its length in relation to the perforations. Therefore in these two systems absolute speed is easily and unambiguously determined, and the speed error *does* determine the pitch and timing errors.

It is usually assumed that in a tape system the "tape speed error" similarly determines the "pitch and timing error". This is only approximately true: even though the tape speed be exactly correct, pitch and timing errors of up to about 1% may occur.

The NAB [1]† and DIN [2] standards for studio recorder/reproducers call for speed errors of ±0.2% or less. In order to meet this specification under all practical conditions it is necessary to use a closed-loop servo system operating from a "control track" recorded on the tape. This is done, in fact, in motion-picture sound systems using tape, in video tape recorders, and in instrumentation tape recorders.

* Presented October 19, 1967 at the 33rd Convention of the Audio Engineering Society, New York.

† Numbers in brackets refer to bibliography at end of paper.

Many of the causes of pitch and timing errors may be avoided or at least minimized if they are recognized by the user. Thus one is usually able to meet the pitch and timing error requirements of practical sound recording systems without resorting to the additional complication and expense of a servo-controlled system.

EXAMPLES OF PITCH AND TIMING ERRORS

Consider a "perfect" recording containing, for example, a 1000 Hz tone, and marker pulses every minute, for a total of one hour. If this record is reproduced, two types of errors commonly occur: these can be demonstrated by using one system with pitch error and no timing error at the end of a given time, and another system with timing error and a constant pitch error. Let us examine these two cases.

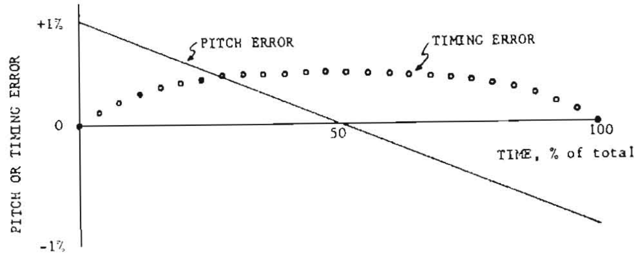

Fig. 1. Pitch and timing error vs time for a system whose pitch error starts at $+1\%$ and falls to -1% at the end.

a. Figure 1 shows the pitch and timing errors of a reproducer whose pitch error is $+1\%$ at the start, decreasing linearly through zero error at 50% of playing time, down to -1% at the end of the playing time. With the machine functioning as a reproducer, the pitch error would probably be unimportant, since it changes so slowly as to be imperceptible. The timing error will first increase, up to a maximum error of 0.5% (9 sec at 30 min, for a one hour total recording); then it will decrease; and at the end of the program there will be no timing error at all.

If a recording were made with this system, and sections from the beginning and the end of the recording were spliced together, a 2% jump in pitch would occur—this would be very noticeable. Thus, such a system might be either very satisfactory or completely unsatisfactory, depending on the application.

b. Figure 2 shows the pitch and timing error of a system with a constant $+1\%$ pitch error. For use as a reproducer, the pitch error would again probably be unimportant, as it is constant. The timing error in seconds will be proportional to the program length—for a one hour program, the error would be 1% in 60 minutes, or 36 sec—an unacceptable amount in most broadcasting situations.

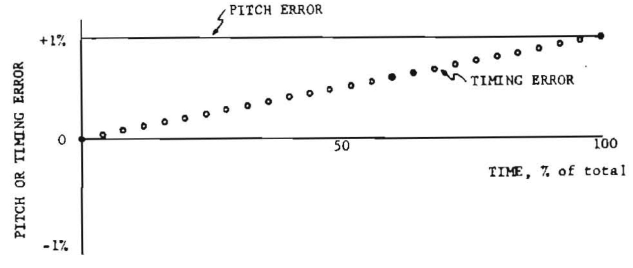

Fig. 2. Pitch and timing error vs time for a system with a constant pitch error of $+1\%$.

If a recording were made with this equipment, and sections from the beginning and end were spliced together, no *change* in pitch error would occur. (If this tape were spliced together with one from another recorder which had no pitch error, a change would of course be heard). Again, this sytem might be either very satisfactory or completely unsatisfactory, depending on the application.

THE SIGNIFICANCE OF TAPE SPEED (IDEALIZED CASE)

First consider some idealizing assumptions about tape. They are usually taken for granted, but it will be shown later that they are not really valid. The assumptions are:

1. The tape is infinitesimally thin compared to the capstan radius, so that the capstan peripheral speed and the tape speed are identical so long as the friction between capstan and tape are high enough that no slipping occurs between capstan and tape.

2. The tape is of unvarying length, i.e., is unchanged by tape tension, relative humidity, and temperature; and has no residual stress. Therefore the reproduced wavelength always equals the recorded wavelength.

Calculation of Tape Speed (Idealized)

Under the above assumptions, the tape speed may be calculated from measurements of the capstan radius r, in meters, and the angular speed Ω, in radians per second ($\Omega = 2\pi N$, where N is the speed in rev/sec): s (in m/sec) $= \Omega r$.

Both r and Ω are subject to many practical errors: for instance, Ω may change with line frequency when a synchronous motor[1] is used; with line voltage when an induction motor is used; and with temperature and tape tension when the motor is compliantly coupled to the capstan by a belt, rubber tire, puck wheel, etc. Since both speed and radius may be measured accurately and unambiguously, and since they are highly variable depending on the design of the particular tape transport, they will not be further discussed here.

Measurement of Tape Speed (Idealized)

Under the conditions assumed above, there are several equally valid methods for measuring the tape speed:

Pulley speed and radius. 1. Measure the shaft speed and radius of the capstan itself, and calculate $s = \Omega r$.

[1] Professional tape recorders often use synchronous motors which run at a speed determined exactly by the power line frequency. A question arises in this case: is the speed error due to power-line frequency errors to be attributed to the tape transport, or to the power line? NAB [1] and IEC [3] standards specify that measurements be made relative to the power-line frequency. Such a choice is rather arbitrary, but must be made one way or the other. In this case, if measurements are made using a commercial power source, timing and counting devices referred to absolute time must **not** be used, but rather devices referred to the power-line frequency such as strobotachometers, frequency-ratio meters, frequency counters which derive their time-base from the power line, etc. The power-line frequency commonly varies $\pm 0.05\%$, which cannot be neglected in comparison to the NAB speed tolerance of $\pm 0.2\%$.

2. Measure the shaft speed and radius of an *auxiliary* measuring pulley driven by the tape (this might be the "reel idler", etc.), and again calculate $s = \Omega r$.

Visual determination of the recorded wavelength. Record two pulses a known time T apart, "develop" the pulses [4] so that their position can be seen and measure the length L between them; calculate the speed from $s = L/T$.

Measurement of frequency or time in reproduction of a known recording. 1. Reproduce a test tape containing a recording of known wavelength λ; measure the reproduced frequency f; calculate speed from $s = f\lambda$. 2. Reproduce a test tape containing a recording of pulses with a known length L between them; measure the reproduced time T; calculate speed from $s = L/T$.

Under the assumptions made, the measuring method may be chosen purely in terms of convenience of measuring apparatus at hand. It will be shown later that under real conditions each of these measuring methods has its faults and limitations.

Pitch and Timing Error from Speed Error (Idealized)

Continuing with these same assumptions, it can be said that the incoming frequency f_{in} is transformed to a recorded wavelength λ_{rec} according to $\lambda_{rec} = s_{rec}/f_{in}$ where s_{rec} is the tape speed in recording. Inversely, the wavelength in reproducing λ_{rep} (which equals λ_{rec}) is transformed back into a reproduced $f_{rep} = s_{rep}/\lambda_{rec}$.

Similarly, an incoming time interval T_{in} is transformed to a recorded tape length L_{rec} according to $L_{rec} = s_{rec} \cdot T_{in}$; and $T_{rep} = L_{rec}/s_{rep}$.

Thus one needs only know the error of the recording and reproducing speed throughout the program length in order to calculate the pitch and timing error:

The pitch error at any instant is equal in magnitude to the speed error at that instant. For reproducing, the sign is the same (that is, high speed gives high pitch); for recording the sign is reversed (high speed gives low pitch).

The timing error for any given interval of time may be found by integrating the speed error vs time over that interval. In recording, the sign is the same (high speed gives long program time); in reproducing, the sign is reversed (high speed gives short program time).

THE INSIGNIFICANCE OF TAPE SPEED (REAL CASE)

The assumptions of the previous sections—that tape thickness is negligible, and tape length is unvarying—are quite necessary in order to relate "tape speed" alone to pitch and timing error. A discussion of the real case, however, will show that the tape thickness is significant, so that the "capstan speed and radius" alone do not determine the tape speed; that, since the tape changes length with tension, and the tape tension changes along its path through the transport, the "tape speed" observed depends on the location along the tape path at which "speed" is measured; and, finally, because of this change of length with tension, plus changes with temperature, humidity, and manufacturing and winding stress, that the reproduced wavelength does not necessarily equal the recorded wavelength, and even a *valid* knowledge of the tape speed does not determine the pitch and timing errors!

Calculation of Tape Speed at the Capstan (Real)

The relationship "tape speed = capstan surface speed" holds only when the tape is infinitesimally thin. Table I lists the capstan radii of several commercial tape recorders, and that of the NAB Standard Speed Measuring Pulley; and the relative thickness of 50 μm total thickness ("regular length") tape. Note that in the USA, the "tape thicknesses" of 0.5 mil (13 μm), 1.0 mil (25 μm), and 1.5 mil (38 μm), etc., refer to the tape *base material only.* Since this specification has no meaning in calculating the tape speed, the *overall thickness* is always used in this paper. Since the tape thickness is in the order of 1% of the shaft radius, and we are concerned with speed tolerances of 0.2% for studio recording, a correction factor is obviously necessary, and the driving of the tape by the capstan must be considered as the complicated rolling process that it really is.

The "effective radius" is approximately to the centerline of the tape; therefore the shaft radius must be *decreased* by approximately one-half of the tape thickness, which is to say that the shaft diameter must be decreased by approximately one tape thickness.

The exact factor depends on whether the coating is more or less compliant than the base; the frictional forces between tape, capstan, and capstan idler; which side of the tape (coating or backing) contacts the capstan; and several other factors which are difficult to analyze accurately. Therefore about the only practical method of determining the tape speed for small capstans is to actually measure the tape speed with a pulley whose diameter is great enough to approximate the "infinitesimally thin tape" condition. The NAB pulley, which is compensated for the tape thickness, is usually satisfactory, though larger pulleys are sometimes used. The diame-

TABLE I. Transports, capstan diameters, and relative thickness of 50 μm (regular) tape.

Transport	Speed cm/sec	Speed in/sec	Approximate Capstan Diameter mm	Relative Thickness of 50 μm (Regular) Tape = Speed Error If Not Compensated For %
Ampex 350	9.5/19	3.75/7.5	3	1.7
Ampex 350	19/38	7.5/15	6	0.8
Ampex 300	19/38	7.5/15	12	0.4
NAB Speed Measuring Pulley	any		36	0.14

ter of the small capstan is then modified according to this measurement in order to achieve the correct tape speed.

One finds experimentally that the speed of the tape corresponds to a point nearer to 38% (rather than 50%) into the depth of the tape, so that the correct capstan size is more closely the calculated diameter less 0.76 times the tape thickness. This results in the sizes shown in Table II for capstans run by "direct drive" synchronous motors on 60 Hz power lines.

TABLE II. Capstan sizes used by Ampex for models 350 and 300, for 60 Hz power-line frequency (5, 10 and 20 rev/s), compensated for 50 μm (regular) tape thickness.

Nominal Capstan Diameter, mm	Specified Capstan Diameter	
	mm	inches
3	2.992– 2.997	0.1178–0.1180
6	6.022– 6.033	0.2371–0.2375
12	12.073–12.080	0.4753–0.4756
36 (NAB Speed Measuring Pulley)	36.335–36.340	1.4305–1.4307

This, unfortunately, is not the end of the matter. If a capstan is corrected for regular (50 μm) tape, the double (25 μm) tape does not run the correct speed. As long as one always uses the same capstan diameter, there is no error of pitch or timing; but if different capstan diameters are used, a pitch and timing error appears.

Table III shows the actual speed errors which occur when 35 μm (double) and 25 μm (triple) tapes are played on the various capstans which have been corrected for 50 μm (regular) tape. The speed errors are seen to be from 0.12 to 0.67%.

TABLE III. Relative speed errors when capstan is compensated for 50 μm tape, but plays 25 or 35 μm tapes.

Nominal Capstan Diameter, mm	Speed Error in % With Given Tape Thickness		
	50 μm (regular)	35 μm (extra)	25 μm (double)
3	0.0	−0.47	−0.67
6	0.0	−0.23	−0.33
12	0.0	−0.12	−0.17

Table IV shows the relative speed errors when the thin tapes are recorded with one capstan diameter and reproduced with another; errors of 0.11 to 0.5% result.

The only solution to these problems is to avoid them: when pitch and timing error are important, either use the thickness of tape for which the capstan was compensated, or else always use the same capstan size. The NAB Standard, in Annex A, "Methods of Tape Speed Measurement", specifies that speed measurements be made with tape having an overall thickness of 48±5 μm (regular).

TABLE IV. Relative speed errors when tape is recorded with one capstan diameter and reproduced with another capstan diameter.

Nominal Capstan Diameter, mm	Speed Error in % With Given Tape Thickness		
	50 μm (regular)	35 μm (extra)	25 μm (double)
3 and 6	0.0	0.24	0.34
6 and 12	0.0	0.11	0.16
3 and 12	0.0	0.35	0.50

Measurement of Tape Speed (Real)

An earlier section described two direct methods for measuring tape speed—by calculation of speed from $s = \Omega r$ of the driving capstan, or of an auxiliary pulley.

However, it has just been shown that one cannot directly measure the effective radius exactly when the tape thickness is significant in comparison to the pulley (capstan) diameter. Thus one is led to measure speed with an auxiliary pulley which may be made large enough to allow an accurate determination of its effective radius. Another practical reason for using the auxiliary pulley is that the tape may slip at the capstan if the tape holdback tension is too great for the capstan idler force and the friction between the tape and the capstan and capstan idler. The capstan speed might be correct but the tape speed wrong: the auxiliary pulley detects this error due to tape slip at the capstan.

But even the auxiliary pulley may give erroneous readings if the pulley is located at the incorrect position in the tape path, because at any instant the speed of the tape changes as the tape goes through the transport. This is due to the elasticity of the tape: the length of a section of tape depends on the strain per unit tension on the tape (a property of the tape materials), and the tension to which it is subjected. Figure 3 shows an example of tensions: the supply tension T_s, of a constant torque machine (say the Ampex 350, on "small reel") is 0.7 N at the beginning of the reel; the tension at the constant-speed capstan, T_c, has increased to 0.84 N, due to the friction of the tape on the heads in the head assembly. The takeup tension T_t is completely independent because of the constant-speed capstan, and is 2.1 N at the beginning of a reel. The strain per unit force for 6.3 mm (¼ in.) tape is about 0.1%/N to 0.3%/N (see Appendix); we will use the value of 0.1%/N (typical for 50 μm regular tapes) in the following examples. The errors could therefore be three times those shown if 25 μm (double) tape were used.

The tension at the supply reel is 0.14 N less than that at the capstan; therefore the speed at the supply reel is actually 0.014% slower than that at the capstan; similarly, the tension at the takeup reel is 1.3 N greater than that at the capstan, and the speed is 0.13% faster than that at the capstan.

This is explained by the fact that the mass of tape flowing by each point per unit time must be the same as

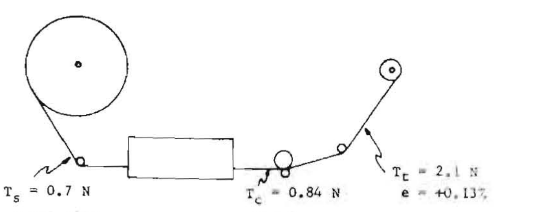

Fig. 3. Tape speed error **e** for different positions in a transport, with fixed reel positions. Tension values are for 6.3 mm tape width.

that flowing by any other point; otherwise tape would be "piled up" in the system. Therefore the speed must increase proportionately when the tape is stretched more, and decrease when the tape is stretched less. Thus, even though the speed at the capstan incoming side remains exactly constant, the speed at the reel idler will be 0.014 to 0.04% slower than the speed at the capstan; and the speed at the takeup reel will be from 0.13% greater to 0.18% less than the speed at the capstan. Thin tapes would further increase this error by some three times.

Thus it can be seen that the actual tape speed at the takeup reel may differ from the true speed at the capstan by 0.2 to 0.5% depending on the tape thickness. Therefore the NAB Standard specifies that the speed measurement is to be made *at a position between the head assembly and the capstan*, because this speed is very nearly the same as the speed at the recording and reproducing heads.

For a tension ratio across the head assembly of 1.2 (typical of the Ampex Model 350) the speed at the reel idler is nearly identical to the speed at the capstan. If a higher friction is present at the head assembly due to more wrap of the tape around the heads and guides, or due to a greater number of heads or guides, the speed at the reel idler may be enough lower than the speed at the capstan to suggest that the reel idler should not be used as the position for the speed-measuring pulley.

It should be emphasized again that this section discusses a problem in *measuring* the tape speed: the *indicated* speed would be in error, even though the *actual* speed might be exactly correct. It should also be recalled that nothing has been said about the pitch or timing errors.

Changes of Wavelength between Recording and Reproducing (Real)

For "tape speed" alone to control pitch and timing errors, the reproduced wavelength must equal the recorded wavelength. In practice, the length of a section of the tape—and therefore the wavelength—varies with the characteristics of the tape (strain per unit force, temperature and humidity coefficients of expansion, and viscoelastic properties), and with the way it is used (tape tensions generated by the transport; temperature and humidity environment in use and storage; and tensions, times, and temperatures of storage of the tape both in the tape manufacturing and in the storage of a finished tape on a reel). To the extent that the wavelength changes from the time of recording to the time of reproducing, tape speed errors and pitch and timing errors may be independent of each other.

Effect of tape tension. It was shown earlier that, due to tape elasticity, the speed of a short section of tape changes as it passes through the transport, since the tensions change with position in the transport, but are assumed constant at a given position during the time it takes this short section to pass through the transport.

Now consider the effect of the tape elasticity on the wavelength, due to the change of tension (and therefore wavelength) that occurs at any given point in the transport—for instance, the head assembly—as the tape is played and one goes from a full supply reel to an empty supply reel.

When a "constant torque supply system" is used (e.g., the Ampex Models 300 and 350), the range of holdback tensions which occurs (including the effect of friction at the heads) is shown in Table V. The resulting wavelength changes are also shown.

Incorrect tensions (as exemplified by the "small/large" example in the table) can greatly increase the wavelength changes; a similar effect occurs when the holdback tension is incorrectly set, or the stopping brake drags in the Play mode. This also shows that a *standard* tape tension is required for all transports if a standard speed is to give uniform pitch and timing.

If the tape speed remains constant at the heads, which is the case for a direct-drive synchronous capstan motor with proper capstan-idler force, the "pitch change" from beginning to end of the supply reel would be the same as the wavelength change: 0.17% for the 18 × 6 cm (small) reels, and 0.13% for the 27 × 11 cm (large) reels, with 50 μm (regular) tape. Use of 25 μm (double) tape will double these errors. Incorrect tensions also may increase the error, with a 1% error occurring with the "small reel—high torque" condition and 25 μm (double) tape.

This pitch change of 0.1% to 1.0% occurs in a transport whose only "imperfection" is the lack of a constant-tension holdback system: the *speed* at the heads is constant here. But as one progresses from the beginning to the end of a reel of tape, the pitch of a recorded tape will change. If the same tape is played without any

TABLE V. Changes in tape tension and resulting change in wavelength at the heads due to change of holdback tension in a "constant torque" transport with 6.3 mm (¼ in.) tape.

		Reel Size and "Reel Size Switch" Setting		
		Small/Small[1]	Small/Large[2]	Large/Large[3]
Tension at heads for given position in supply reel	Full	0.8 N	1.6 N	1.2 N
	Middle	1.2 N	2.4 N	1.5 N
	Empty	2.5 N	5.0 N	2.5 N
Change in tension at heads, from full to empty supply reel		1.7 N	3.4 N	1.3 N
Change in wavelength at the heads, from full to empty supply reel				
With 50 μm (regular) tape		0.17%	0.34%	0.13%
For a range of tapes		0.14 to 0.5%	0.28 to 1.0%	0.1 to 0.4%

[1] Small reels, 18 × 6 cm (7 × 2.3in.); on "small reel" position, torque = 0.06 N·m.
[2] Small reels, 18 × 6 cm; on "large reel" position, torque = 0.12 N·m.
[3] Large reels, 27 × 11 cm (10.5 × 4.5 in.); on "large reel" position, torque = 0.12 N·m.

editing on the machine on which it was recorded, this error is completely compensating, and no error will be seen in the pitch or timing. If, on the other hand, one section of tape is taken from the beginning of a reel, and edited to the end, etc., or if the recording is transferred to a different-size reel, or a different location on the reel, the pitch and timing errors will be apparent.

The use of constant holdback tension eliminates this particular problem completely. There are several commercial audio recorders which do incorporate constant-tension holdback systems.

Effect of Temperature Change. Published values for the temperature coefficient of linear expansion for tape base materials are: $5.4 \times 10^{-5}/°C$ for acetate and $1.7 \times 10^{-5}/°C$ for polyester [5]. Thus, if the temperature changed from 20 to 35°C (68 to 95°F), the change in recorded wavelength (and therefore the pitch and timing errors) would be 0.08% for acetate base and 0.025% for polyester.

Effect of Humidity Change. Published values for the hygroscopic (humidity) coefficient of linear expansion for tape base materials are 150×10^{-6} % RH for acetate, and 6×10^{-6} % RH for polyester. Thus, if the humidity changed from 30 to 70%, the change in recorded wavelength (and therefore pitch and timing errors) would be 0.6% for acetate base, 0.024% for polyster.

Effect of Viscoelastic Characteristics. It is a well-known fact [6] that the base materials used for magnetic tape are "viscoelastic": that is, when subjected to a stress, there is an elastic strain which takes place immediately and an additional viscoelastic strain that continues as long as the stress is applied. When the stress is removed, the elastic strain is immediately recovered, but the viscoelastic strain takes a long time to recover. These effects are dependent not only on the base material, but also on the temperature: higher temperatures accelerate the rate of viscous strain.

Two problems are of concern here:

1. When the base material is manufactured, a "residual stress" is left in the material. DuPont literature for Mylar [5] shows a residual strain of 0.5% at a 100°C temperature. (This temperature could occur during storage and shipment, although the plastic reels would show obvious damage from this temperature.) Even under lesser temperatures, the stress tends to relieve itself, although more slowly. When the tape is dried in an oven after coating, part of this stress is relieved. Specifications are not published on commercial tapes, and this data is somewhat difficult to measure accurately. Preliminary tests were performed by the Ampex Magnetic Tape Laboratory on tapes purchased on the open market: a sample's length was measured; it was left in a 60°C environment for 8 hours, then returned to room temperature and measured again. In six samples of polyester-based tapes, shrinkages of 0.008%, 0.07%, 0.03%, 1.7% were measured, and two samples showed an *expansion* of 0.02% and 1.7%! One can only guess that the history of the samples was different, and that this was the major factor.

2. After the tape is wound on a reel under tension—by the manufacturer or by a user—viscoelastic elongation also occurs until the stress is relieved. This very complicated problem has been reported on by Tramposch [7, 8]. The tape manufacturer usually winds the tape under a rather high tension to minimize the chance that the tape pack will lose its tension—and consequent "firmness"—during shipment. (When this does happen, the shock received in shipment may ruin the reel of tape.) Suppose that the user makes a recording on a new reel of tape which has this built-in residual stress; when he winds the tape on a reel at a *lower* tension than that used by the tape manufacturer, the tape will shrink, and the wavelength will change. It is possible that this was the cause of the 1.7% shrinkage reported in the previous paragraph—we really don't know as yet exactly how much pitch and timing error can occur from this cause.

Pitch and Timing Error (Real)

An earlier section discussed the calculation of pitch and timing errors in the idealized case from a knowledge of the tape speed only. The discussion on the calculation of the real tape speed at the capstan shows possible speed errors of up to 2%, which might be overlooked. But as shown in the discussion of changes of wavelength, changes in tape tension, temperature, humidity, and viscoelastic elongation all cause the wavelength to change between recording and reproducing, and this causes a corresponding pitch and timing error which adds to the errors from speed alone.

Thus it is possible to calculate the real pitch and timing errors (other than those from viscoelastic elongation) if sufficient care is taken. In general, however, it is more practical simply to measure errors of an actual system.

PRACTICAL MEASUREMENT TECHNIQUES AND PROBLEMS

If a measurement accuracy of about ±1% is adequate, one may consider that speed, timing, and pitch errors are synonymous, and use any of the measurement techniques outlined in the section on the measurement of speed for the idealized case.

If accurate measurements are required, one must measure speed, timing, and pitch errors separately, being careful to define exactly the system being measured: some errors are due to the transport alone (e.g., wrong capstan speed; tape slip at the capstan); some are due to the tape alone (e.g., changes due to temperature, humidity, and the relief of manufacturing stresses); and some are due to the tape-and-transport interaction (e.g., tape thickness/capstan diameter; tape elasticity/transport tensions; tape elongation due to winding stresses left by transport, and viscoelastic properties of the tape.)

Speed Error Measurement

Speed, timing, and pitch errors must all be referred eventually to the tape speed at a specified tape tension. The tape speed may be measured with 50 μm (regular) tape, by a correctly designed pulley[2] placed between the head assembly and the capstan. The measurement should be made at least at the start, middle, and end of the supply reel, and the greatest error reported.

[2] A pulley suitable for this measurement is manufactured by Dubbings Electronics, Copiague, New York. The diameter should be checked, as earlier models did not include the tape thickness correction; the dimension should be that shown in Table II.

Direct speed measurement has the advantage of not requiring a special test tape; also, tape length variations due to tension, temperature, and humidity variations, and residual stress and viscoelastic elongation are eliminated. The disadvantage is that correct tape speed does not guarantee correct pitch and timing, for exactly these reasons.

Pitch Error Measurement

The pitch error of a reproducer may be measured directly by reproducing a test tape containing a recording made at a known tension with a known frequency (i.e., at known speed of known wavelength). As with the speed error measurement, the pitch error measurement must be made at the start, middle, and end of the supply reel, and the greatest error reported.

The error of the reproduced frequency may be measured by one of the following methods:

1. Frequency relative to the power-line frequency (as specified in the NAB Standard [1] and IEC Standard [3]) is measured by a frequency meter which uses the power line as a time-base reference, e.g., the Hewlett-Packard Electronic Counter Model 5211 A. The pitch error in percent is then $e = 100\ (f_{rep}-f_{rec})/f_{rec}$. Any convenient frequency may be used; 1000 Hz would be especially convenient, because the error then reads directly: the last place of a four-place counter is parts-per-mil (tenths of a percent). Many frequency counters have a crystal oscillator for an "absolute" time base, but can also be connected to read frequency *ratio* instead. If we then let R_{rec} represent the ratio of the frequency recorded on the "perfect" test tape to the power-line frequency in recording, and R_{rep} the ratio of the frequency reproduced to the power line frequency in reproduction, the error in percent is: $e = 100\ (R_{rep}-R_{rec})/R_{rec}$.

2. Frequency error is measured by the "drift" meter of a flutter and drift meter, such as the MICOM Model 8100; the WOELKE (Gotham Audio) Model ME 101 or 102, or the EMT Model 420. The frequency on the test tape must correspond to that for which the flutter meter is designed: 3000 Hz has been the standard frequency used in the USA; the "Preferred Frequency" [9] of 3150 Hz is used in Germany, and in the German-made flutter meters (EMT and Woelke/Gotham Audio) and has been proposed for use in the USA. All of these meters have internal oscillators with a frequency accuracy of better than ±0.1% which is used to set the "zero" point of the drift meter. Therefore, unfortunately, none of these meters takes line-frequency errors into account, but rather charges them to the tape plus transport system.

3. Time is measured for a 2π radian phase shift (i.e., 360°, one full cycle) of the reproduced frequency. (This method is especially convenient when the specialized equipment for methods 1 and 2 is not available, because only an ordinary oscilloscope with line synchronization is needed.) The frequency is most conveniently that of the power line used, i.e., 50 Hz or 60 Hz. When the oscilloscope is synchronized to the power line, the wave reproduced from the test tape will appear to drift forward or backward with time, depending on whether the pitch is high or low. The pitch error may be calculated as the ratio of the period of the recorded signal (i.e., the time for one cycle), to the time that it takes for one cycle of the reproduced wave to drift by, due to pitch error. Since the period T is the reciprocal of the frequency, when the power-line (which is the recorded signal) frequency is 50 Hz, $T = 20$ msec; for 60 Hz, $T = 16.7$ msec. Therefore the error in percent is $e = 100\ T =$ "t." For 50 Hz, e (in percent) $= 2/t$, for 60 Hz, e (in percent) $= 1.7/t$. For the NAB and DIN specifications of "speed" error, ±0.2%, the time for one cycle to pass the reference point must be at least 10 sec for a 50 Hz line, 8.5 sec for a 60 Hz line. This method is most convenient with systems which have less than about 2% error: otherwise the measuring time for one cycle is less than 1 sec, and accurate measurement of the time with a stopwatch becomes impractical.

These methods all measure the pitch error directly. The inherent disadvantage is the need for an accurate test tape. "Accurate" includes not only the accuracy of recording in the first place (recording speed, tension, and frequency), but also the errors due to the length-changing effects of the tape. In other words, the "tape plus transport" system is measured. If special care is not taken, one may falsely conclude that the transport has pitch error, when in fact the test tape is at fault.

Thus far, no accurate pitch error test tape is known. Acetate tapes have too high a coefficient of expansion with humidity, and some polyester tapes have too high a residual stress and viscoelastic flow. A completely stress-relieved polyester is being investigated, in hopes that it may be satisfactory for such a test tape. The question of viscoelastic changes due to stress relief while the tape is wound on the reel also still remains unanswered.

The Ampex Flutter Test Tapes contain an approximately 3 kHz tone which is sometimes used for pitch error measurements. It should be pointed out that only the *flutter* on this tape is closely controlled, as its purpose is flutter measurement. Because of the residual stress problem with polyester bases, the flutter test tapes are made on acetate base, which has a high humidity coefficient of expansion; therefore these tapes are not suitable for precision pitch error measurements. Since this is the case, neither the input frequency, the speed, nor the tension is accurately controlled in making these tapes: the wavelength may be in error by as much as ±0.4%, in addition to the error due to humidity changes.

If a suitable material could be found for the tape base, then it would be desirable and possible to control accurately the wavelength in manufacturing flutter test tapes; then they could be used for pitch error measurements also. In the meanwhile, these flutter test tapes should not be used for *precision* pitch error measurements.

Timing Error Measurement

The timing error of a reproducer may be measured directly by reproducing a test tape containing a recording having a known time interval when recorded at a known tape tension and speed. The same problems with changes in tape length occur as in the pitch error measurement described above. As discussed before, the timing error measurement will depend on the reel sizes, length of program, etc. Therefore a particular measurement is valid only for a particular condition: "a 30

minute program, 540 m of 50 μm tape on a 18 × 6 cm reel, at 19 cm/sec, reproduced with a timing error of ± .. sec." ("A thirty minute program, 1200 ft. of 2 mil tape on a 7 × 2.3 in. reel, at 7.5 ips reproduced with a timing error of ± .... sec").

TRANSPORT MAINTENANCE PROBLEMS

Speed, pitch, and timing errors in a professional audio recorder/reproducer which was correctly designed to begin with can usually be traced to one or more of the following problems:

1. Wrong capstan speed in "indirect" (rubber-tired) drives. Test for this problem by measuring the capstan speed with a stroboscope sticker on the capstan. Check at the beginning, middle, and end of a full reel of tape. Adjust as required, per the instruction book.
2. Tape slips at the captstan. This can be caused by a dirty capstan or capstan idler; by low capstan idler force (wrong adjustment—too loose); by capstan idler solenoid not "bottoming" (wrong adjustment—too tight); or by a holdback tension which is too high—see below.
3. Incorrect tape tension. This may be caused by incorrect adjustment of the resistors which set the tension; by excessively high or low line voltage; by dragging of a "stopping" brake—usually due to incorrect brake solenoid adjustment; by an incorrectly set "reel size" switch; or, on a constant-tension system such as the MR-70, due to a failure in the constant-tension system.

Problems similar to these can of course occur in any type of tape transport.

CONCLUSIONS

The NAB Standard calls for a maximum tape speed error of ±0.2%. The NAB speed measuring procedure must be followed carefully if speed measuring errors larger than this tolerance are to be avoided.

This "speed error" tolerance should not be interpreted as guaranteeing that the pitch or timing error will also be better than ±0.2%, since speed measurement alone does not take into account pitch and timing errors due to tape length and tension changes. A standard tape tension would need to be established if "speed" were to be meaningful. This tension would probably be per unit tape width, and might even be different for different tape thicknesses.

In the case of a practical problem with either pitch or timing, one must be careful to measure the actual system and phenomenon of concern, under the actual conditions which prevail. As mentioned at the beginning of this paper, a system may be perfectly satisfactory for one usage but unsatisfactory for another. With the information in this paper, one should be able to choose the important factors and ignore the irrelevant ones.

APPENDIX

Tape Strain per Unit Force

An elastic material placed in tension will stretch. The relative elongation, $\Delta l/l$, is called the strain, ϵ. The strain per unit force, ϵ/f, may be measured directly for a given length of tape or it may be calculated from the formula $\epsilon/f = 1/AY$, where **A** is the cross-sectional area of the tape, and **Y** is the Young's (stretch) modulus of the tape. The Young's modulus is a bulk property of the material; the values for the commonly-used tape base materials are given in Table AI, taken from the base manufacturer's specifications.

TABLE AI. Young's modulus of common tape base materials.

Material	Young's Modulus of Base, GN/m²	Young's Modulus of Coated Tapes, GN/m²
Cellulose acetate	2.3	1.9–3.1
Polyester	3.8	2.1–3.6
Polyester, tensilized	5.5	3.2–5.6

Actually, the Young's modulus of the tape **coating** itself may be considerably greater or less than that of the base material, so that the Y modulus of the base alone is of very limited value. The effective Y modulus range for **coated** tapes is given by Krones [10], and these values are also shown in Table AI.

Because of this wide spread of effective Y modulus values, it is more satisfactory to consider directly the measured values of strain per unit force (ϵ/f) than to try to calculate values from the cross-sectional area and the Y modulus. Krones tabulates the values for strain for a 10 N load for 40 European and USA tapes, with acetate, polyester, tensilized polyester, and polyvinyl chloride bases. Table AII is taken from Krones' summary.

TABLE AII. Strain per unit force for manufactured 6.3 mm (¼ in.) wide tapes.

mm × μm	Length Designation	ϵ/f, %/N minimum	average	maximum
6.3 × 50	regular	0.08	0.10	0.14
6.3 × 35	extra	0.12	0.16	0.23
6.3 × 25	double	0.10	0.18	0.3

Thus, for 6.3 × 50 (regular) tapes, a good value is 0.1%/N (1 N = 3.6 oz). The 6.3 × 25 (double) and 12 μm (quadruple) tapes, and narrower tapes (3.8 mm tapes used in cassettes), would have still higher ϵ/f values.

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THE AUTHOR

John G. McKnight was born in Seattle, Washington in 1931 and received his B.S. degree in electrical engineering from Stanford University in 1952. He has been with Ampex Corporation since 1953 except for the years 1954-56 when he was assigned to the engineering staff of the U. S. Armed Forces Radio Service in New York. In 1959 Mr. McKnight became manager of the advanced audio section of the Professional Audio Division at Ampex. He is presently staff engineer with the Consumer and Education Products Division of the company in Los Gatos, California.

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WEIGHTED PEAK FLUTTER MEASUREMENT:
A SUMMARY OF THE NEW IEEE STANDARD

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THE EXISTING USA "FLUTTER CONTENT" STANDARD (IEEE NR. 193-1953 AND ANSI Z57.1-1953) HAS BEEN REPLACED BY A NEW "WEIGHTED PEAK FLUTTER" STANDARD (IEEE NR. 193-1971 AND ANSI S4.3-DRAFT). IT STANDARDIZES THE FLUTTER METER SPECIFICATIONS, THE MEASURING PROCEDURES, AND THE FORM FOR REPORTING RESULTS. TECHNICAL REQUIREMENTS ARE IDENTICAL WITH THOSE OF CCIR AND GERMAN STANDARDS, AND AN IEC DRAFT.

1. INTRODUCTION

A NEWLY-PUBLISHED IEEE STANDARD NR. 193-1971, "METHOD OF MEASUREMENT FOR WEIGHTED PEAK FLUTTER OF SOUND RECORDING AND REPRODUCING EQUIPMENT" [1] IS NOW AVAILABLE, AND THIS SHORT REPORT SUMMARIZES ITS CONTENTS. THE TECHNICAL BACKGROUND OF THE NEW STANDARD IS TO BE PUBLISHED IN THE NEAR FUTURE [2],[3].

THE ADVANTAGES OF THIS NEW METHOD OVER THAT SPECIFIED IN THE PREVIOUS IEEE AND ANSI STANDARD [4] ARE AS FOLLOWS:

1. THE RANKING OF THE DEGRADATION OF SOUND QUALITY DUE TO FLUTTER, WHEN MEASURED OBJECTIVELY WITH THE WEIGHTED PEAK FLUTTER MEASUREMENT, WILL PREDICT FAIRLY WELL THAT WHICH WOULD BE GIVEN BY A LISTENING PANEL JUDGING "SUBJECTIVE FLUTTER". (THE MEASUREMENT OF "FLUTTER CONTENT" [4] BORE LITTLE RELATIONSHIP TO HOW A RECORDER WOULD SOUND.)

2. THE REQUIREMENTS FOR THE MEASURING EQUIPMENT--THE FLUTTER METER--THAT ARE GIVEN IN THE NEW STANDARD ARE SUFFICIENTLY COMPLETE THAT DIFFERENT EQUIPMENT BUILT TO THIS STANDARD WILL NOT ONLY GIVE THE SAME READINGS ON A CALIBRATING SINE-WAVE, BUT WILL ALSO GIVE THE SAME READINGS ON A DYNAMIC FLUTTER WAVEFORM. (THE PREVIOUS STANDARD [4] GAVE ONLY GENERAL RANGES FOR REQUIREMENTS, AND NO SPECIFIC REQUIREMENTS FOR THE DYNAMIC RESPONSE.)

3. MEASUREMENTS ACCORDING TO THE NEW STANDARD ARE IDENTICAL TO THOSE USED INTERNATIONALLY IN STANDARDS OF THE CCIR AND IN THE IEC DRAFT; AND TO THE GERMAN STANDARD WHICH HAS BEEN WIDELY USED IN EUROPE. THIS GREATLY ENHANCES THE EXCHANGE OF INFORMATION ON RECORDER PERFORMANCE, AND FACILITATES SALES AND PURCHASES OF EQUIPMENT IN OVERSEAS AREAS.

2. SCOPE

"THIS STANDARD SPECIFIES THE WEIGHTED PEAK METHOD OF MEASUREMENT FOR PREDICTING SUBJECTIVE FLUTTER OF SOUND RECORDERS AND REPRODUCERS FOR NORMAL AUDIO USAGE" [1, SEC. 1].

3. DEFINITIONS

"FLUTTER, WOW, DRIFT, AND FREQUENCY-MODULATION NOISE ARE ALL FORMS OF DISTORTION CAUSED BY UNDESIRED FREQUENCY MODULATION INTRODUCED INTO THE SIGNAL BY AN IRREGULAR MOTION OF THE RECORDING MEDIUM DURING THE RECORDING, DUPLICATING, AND/OR REPRODUCING PROCESSES " [1, SEC. 2]. ALTHO FLUTTER, WOW, DRIFT, AND FREQUENCY-MODULATION (FRICTION) NOISE ("SCRAPE FLUTTER") ARE DEFINED, THE STANDARD COVERS ONLY THE MEASUREMENT OF WEIGHTED PEAK FLUTTER.

WEIGHTING IS DEFINED AS "THE USE OF A PSYCHOACOUSTICALLY DETERMINED TIME-RESPONSE AND FREQUENCY-RESPONSE IN AN OBJECTIVE MEASURING EQUIPMENT. THIS IS DONE IN ORDER TO OBTAIN INDICATIONS WHICH BETTER PREDICT THE SUBJECTIVE VALUES THAN WOULD WIDEBAND MEASUREMENT WITH A METER HAVING EITHER AN INSTANTANEOUS TIME RESPONSE, OR A LONG-TIME AVERAGE OR RMS RESPONSE.

WEIGHTED PEAK FLUTTER IS DEFINED AS "FLUTTER AND WOW INDICATED BY THE WEIGHTED PEAK FLUTTER MEASURING EQUIPMENT SPECIFIED IN IEEE STANDARD NR. 193-1971" [1, SEC. 2].

4. THE FLUTTER METER

4.1 THE FLUTTER METER SPECIFICATION

"THE MEASURING EQUIPMENT SHALL CONSIST OF A FREQUENCY DEMODULATOR WHICH PRODUCES AN OUTPUT VOLTAGE PROPORTIONAL TO THE RELATIVE FREQUENCY CHANGE (DELTA F/F), FOLLOWED BY A WEIGHTING FILTER, A PEAK RECTIFIER AND AN INDICATOR" [1, SEC. 5].

THE TEST FREQUENCY NOW SPECIFIED IS THE "PREFERRED FREQUENCY" OF 3150 HZ.

THE RESPONSE CURVE OF THE COMBINATION OF THE DEMODULATOR, THE WEIGHTING FILTER, AND THE INDICATOR IS TO BE AS SHOWN IN FIG. 1.

A PEAK-TO-PEAK RECTIFIER IS USED, BUT THE METER IS CALIBRATED IN THE PEAK VALUE (ONE-HALF OF THE PEAK-TO-PEAK VALUE).

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WEIGHTED PEAK FLUTTER MEASUREMENT: A SUMMARY OF THE NEW IEEE STANDARD

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THE DYNAMIC CHARACTERISTICS OF THE FLUTTER METER ARE SPECIFIED IN TERMS OF THE INDICATION FOR A PULSE-TRAIN OF FREQUENCY MODULATION AS SHOWN IN FIG. 2. THE PULSES HAVE CONSTANT AMPLITUDE, CONSTANT 1 S REPETITION RATE, AND ADJUSTABLE LENGTH OF 10 MS TO 100 MS. THEY HAVE THE SAME PEAK-TO-PEAK AMPLITUDE AS THE 4-HZ SINE WAVE. THE FLUTTER METER READING WITH THE SINE WAVE OF FREQUENCY MODULATION IS TAKEN AS REFERENCE (100%). THEN THE RELATIVE METER READINGS ARE MEASURED FOR THE PULSE-TRAIN OF FREQUENCY MODULATION. THE FLUTTER METER READINGS MUST BE AS SHOWN BELOW (TOLERANCES ARE ALSO GIVEN IN THE STANDARD):

PULSE LENGTH,	A MS	10	30	60	100
RELATIVE INDICATION,	B %	21	62	90	100

THE OTHER DYNAMIC REQUIREMENT IS FOR THE DECAY TIME: WHEN THE 100 MS PULSE IS USED WITH A 1 S REPETITION RATE, THE DECAY TIME OF THE FLUTTER METER MUST BE SUCH THAT BETWEEN THE PULSES THE INDICATOR FALLS TO A READING OF FROM 36% TO 44% OF THE MAXIMUM.

A NUMBER OF "GOOD ENGINEERING PRACTICE" ITEMS ARE GIVEN: THE INSTRUMENT SHOULD WORK WITH TEST FREQUENCIES BETWEEN 3000 HZ AND 3300 HZ, IN ORDER TO ALLOW USE WITH OFF-SPEED RECORDERS OR REPRODUCERS, AND ALSO WITH BOTH OLD TEST RECORDS AT 3000 HZ, AND NEW TEST RECORDS AT 3150 HZ. A BASIC ACCURACY OF AT LEAST + OR - 10% OF FULL SCALE IS SUGGESTED. A REQUIRED INPUT VOLTAGE OF NOT MORE THAN 100 MV IS SUGGESTED, AND AN INPUT IMPEDANCE OF NOT LESS THAN 300 KILOHMS AT 3150 HZ. FINALLY, PROVISION FOR CONNECTING EXTERNAL EQUIPMENT (FOR EXAMPLE, AN OSCILLOGRAPH) WITH OR WITHOUT THE WEIGHTING FILTER IS SUGGESTED.

4.2 AVAILABILITY OF FLUTTER METERS AND TEST RECORDS

SINCE THE "WEIGHTED PEAK FLUTTER" MEASUREMENT IS IDENTICAL TO THE "DIN WEIGHTED" MEASUREMENT WHICH HAS BEEN USED FOR SOME 10 YEARS NOW, COMMERCIAL FLUTTER METERS WHICH MEASURE TO THE GERMAN STANDARD DIN 45 405-1966 MAY BE USED. SUCH INSTRUMENTS ARE AVAILABLE FOR INSTANCE FROM GOTHAM AUDIO CORP, NEW YORK, NEW YORK; AND MINCOM DIV. OF 3M, CAMARILLO, CA (THESE INSTRUMENTS WERE DEVELOPED BY BAHRS INDUSTRIES, AND MANUFACTURED ORIGINALLY BY MICOM, LATER CALLED DMC).

TEST RECORDS WITH A 3150-HZ SIGNAL WHICH MAY BE USED FOR FLUTTER MEASUREMENTS ACCORDING TO THE NEW STANDARD MAY BE OBTAINED FOR INSTANCE FROM THE FOLLOWING COMPANIES:

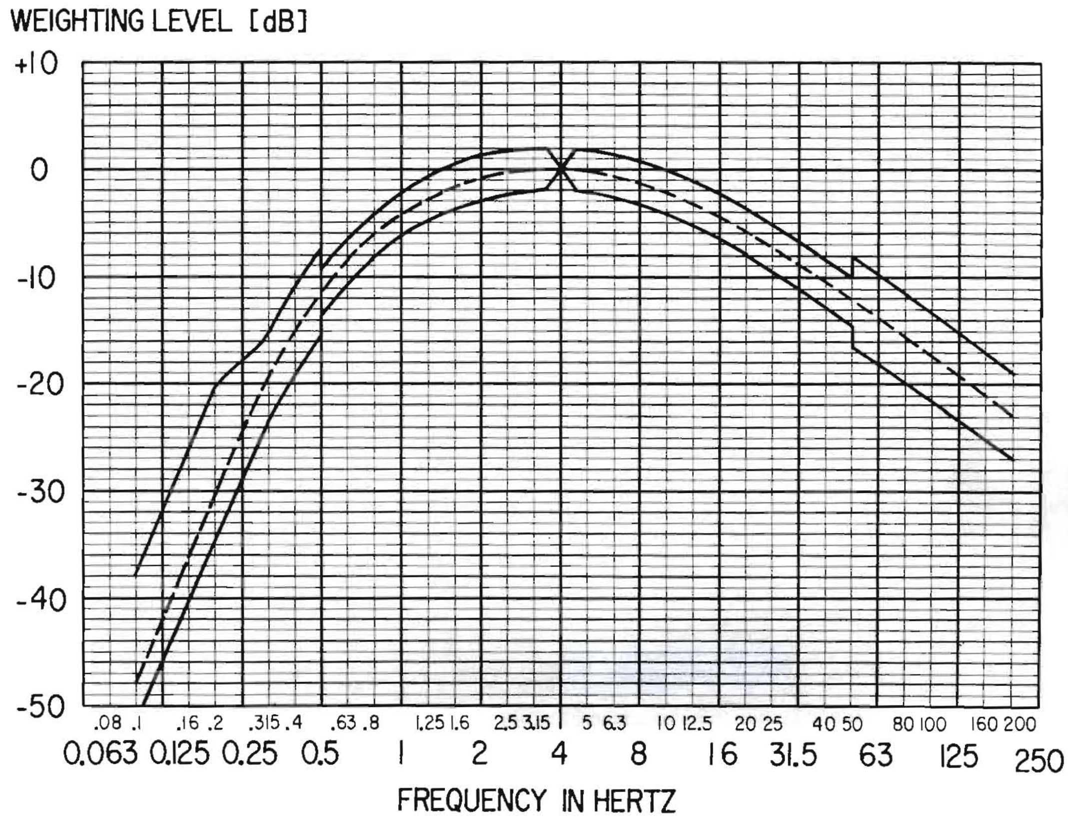

FIG. 1 WEIGHTING CURVE

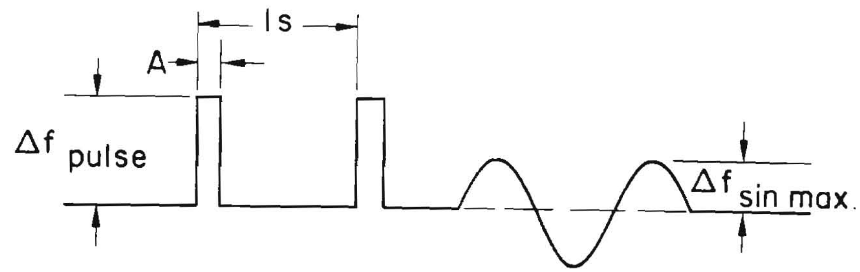

FIG.2 PULSE FOR MEASURING DYNAMIC CHARACTERISTICS

TAPE RECORDS:	AMPEX CORPORATION, REDWOOD CITY, CA. THE STANDARD TAPE LAB, OAKLAND, CA.
16-MM AND 35-MM MOTION PICTURE FILM RECORDS:	THE STANDARD TAPE LAB, OAKLAND, CA.
DISC RECORDS:	GOTHAM AUDIO CORP, NY, NY.

5. MEASUREMENT PROCEDURE

"THE MEASUREMENTS OF NORMAL RECORDING AND REPRODUCING SYSTEMS SHALL BE MADE ON ONE ELEMENT ONLY OF THE SYSTEM (EITHER THE RECORDER OR THE REPRODUCER, BUT NOT ON BOTH) UNDER SUCH CONDITIONS THAT THE WEIGHTED PEAK FLUTTER IN THE REMAINING PARTS OF THE MEASURING SYSTEM IS NEGLIGIBLE.

NOTE: WHEN THIS CONDITION CANNOT BE FULFILLED, A RECORDER/REPRODUCER MAY BE MEASURED BY RECORDING A 3150 HZ TEST FREQUENCY AND SUBSEQUENTLY REPRODUCING THIS RECORD SEVERAL TIMES, MEASURING IN EACH CASE THE TOTAL WEIGHTED PEAK FLUTTER AND CALCULATING THE ARITHMETIC AVERAGE VALUE OF THESE MEASUREMENTS. WEIGHTED PEAK FLUTTER SHALL NOT BE MEASURED WHILE SIMULTANEOUSLY RECORDING AND REPRODUCING" [1, SEC. 3.3].

IF, BECAUSE OF RANDOM FLUTTER OR VERY LOW-FREQUENCY FLUTTER, THE READING VARIES WITH TIME, THE MAXIMUM VALUE SHALL BE READ AND REPORTED.

SINCE, IN MOST SYSTEMS, SYSTEM CONDITIONS VARY IN SUCH A MANNER AS TO GIVE DIFFERENT FLUTTER READINGS, A CHOICE OF REPORTING FORMS IS GIVEN: EITHER REPORT THE READING FOR EACH CONDITION, OR ELSE GIVE THE READING FOR THE WORST COMBINATION OF FACTORS.

6. REPORTING RESULTS

WEIGHTED PEAK FLUTTER SHOULD BE REPORTED IN THE FOLLOWING MANNER:

"WEIGHTED PEAK FLUTTER OF THE RECORDER [REPRODUCER] [RECORDING AND REPRODUCING SYSTEM]: ± %" [1, SEC 4].

THE SIGN "±" IS USED TO INDICATE THAT THE PEAK, RATHER THAN PEAK-TO-PEAK VALUE HAS BEEN GIVEN.

A STATEMENT OF CONDITIONS MAY ALSO BE REQUIRED--FOR EXAMPLE,FOR A TAPE RECORDER, THE SPEED AND THE REEL SIZE (MINIMUM HUB DIAMETER, MAXIMUM OUTSIDE DIAMETER, ETC.).

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[1] "METHOD OF MEASUREMENT FOR WEIGHTED PEAK FLUTTER OF SOUND RECORDING AND REPRODUCING EQUIPMENT", IEEE STANDARD NR. 193-1971, AND ANSI S4.3-DRAFT. AVAILABLE FROM IEEE, N.Y.,N.Y. TO BE PUBLISHED IN IEEE TRANS. AUDIO AND ELECTROACOUSTICS AU-20, NR. 1 (1972).

[2] E. BELGER, "ON MEASURING FREQUENCY VARIATIONS", TO BE PUBLISHED IN IEEE TRANS. AUDIO AND ELECTROACOUSTICS AU-20, NR. 1 (1972).

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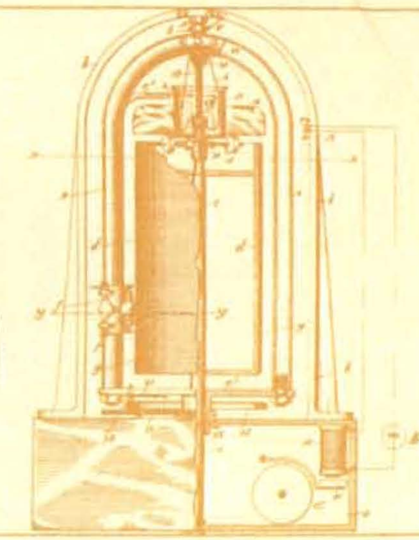
[4] "METHODS FOR DETERMINING FLUTTER CONTENT IN SOUND RECORDERS", OBSOLETE IEEE STANDARD NR. 193-1953 AND ANSI Z57.1-1954.

AUDIO TECHNICAL INFORMATION NUMBER 1



Maximum Signal-to-Noise Ratio of a Tape Recorder

by J. C. Mallinson
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ABSTRACT

Using the Wiener auto-correlation theorem, the noise power spectrum of the pole strength in a thin lamina of an erased tape is shown to be approximately "white." The noise power spectrum of the reproduce head voltage is calculated for a thick tape and compared with the signal power. The wideband signal-to-noise ratio of a tape recorder equalized flat is deduced and expressed in very simple forms, which are inversely dependent upon the square of a bandwidth. Notably, in this special case the wideband result is independent of reproduce head-to-tape spacing. Numerical examples demonstrate that this simple theory yields results in excellent agreement with practice.

INTRODUCTION

The signal-to-noise ratio (SNR) of a tape recorder is, with the possible exception of the "drop-out" behavior, the most important factor governing its utility as an information storage system. The maximum possible SNR, which occurs when the principal noise source in the system is the tape itself, depends naturally not only upon the fundamental parameters of the tape but also upon the manner of its use. The discussions of SNR given previously,[1,2] though correct, seem to be needlessly complex. Further, the results are not in forms readily useable by the system designer. In the present paper the entire problem is reworked in a simple, direct manner using the Wiener auto-correlation theorem.

It is shown that the wideband SNR may be expressed in very simple forms which yield values in exceptionally close agreement with experiment. Several new relationships of practical significance are derived and discussed. Further, since all the important expressions are derived from first principles, it is believed that the work is not without pedagogic merit.

INITIAL CONSIDERATIONS

Whereas the signal in a tape recorder relates to the mean magnetization of the tape particles, the noise arises from the deviations from the mean of the magnetization. In an erased tape the major source of these deviations is the randomness of the particle magnetization directions. We shall assume that only two directions exist, positive and negative, which are occupied at random.

As the tape becomes magnetized and the directional randomness decreases, one might expect the noise to decrease. In fact, it increases somewhat, probably due to non-uniform particle packing effects. A noise which depends upon the signal (modulation noise) is neither stationary nor additive. However, since in the best tapes the noise increase is slight ($\approx$ 3-4 dB), we shall assume here that the noise is stationary and additive at all signal levels.

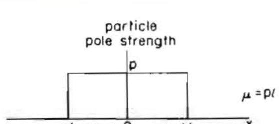

FIGURE 1. Particle pole strength.

TAPE MAGNETIZATION STATISTICS

We seek first the auto-correlation function (ACF), taken in the direction of head-to-tape motion (x), of the pole strength* in a lamina, of width ω and thickness δy, of an erased, oriented, particulate, tape. Suppose the single domain particles be identical, have dipole moment $\mu = pl$ (see Fig. 1) and be at a density n. The pole strength of the lamina, at longitudinal position x, is,

$$P(x) = \sum_i b_i\, p_i(x)$$

$$\text{where } b_i = \pm 1 \text{ at random} \tag{1}$$

The ACF is, by definition for stationary random processes,[3]

$$\text{ACF}(x') = \lim_{x \to \infty} \frac{1}{x} \int_{-x/2}^{+x/2} P(x)\, P(x-x')\, dx \tag{2}$$

$$= \lim_{x \to \infty} \frac{1}{x} \int_{-x/2}^{x/2} \sum_i b_i\, p_i(x) \sum_j b_j\, p_j(x-x')\, dx \tag{3}$$

$$= n\, \omega\, dy \int_{-\infty}^{+\infty} p(x)\, p(x-x')\, dx$$

$$\text{since } \overline{b_i b_j} = 1 \text{ if } i = j$$
$$= 0 \text{ if } i \neq j$$

*The pole strength is defined by $P(x) = \int_A M(x)\, dA$, where M(x) is the magnetization and A is the cross sectional area.

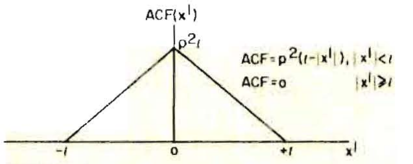

FIGURE 2. Auto-correlation function of particle pole strength.

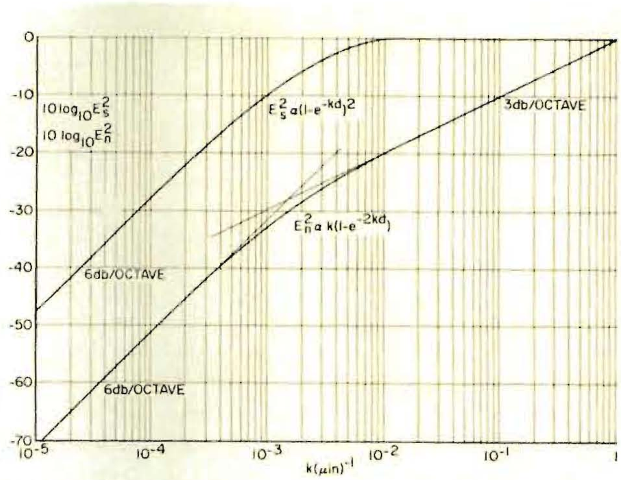

FIGURE 4. Relative signal and noise power spectra versus wavenumber (k) for a 400 μinch coating. No head-to-tape spacing effect is shown since it would change both curves equally.

Since, on the average, the particles only correlate with themselves, the lamina pole strength ACF is simply the sum of the individual particle pole strength ACF's, each of which is equal to $p^2\ (l - |x'|)$ (see Fig. 2). According to the Wiener theorem the noise power spectrum is given by the Fourier cosine transform of the ACF.[4] Thus the noise power spectrum of the lamina pole strength is:

$$\Theta(k) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} n\,\omega\,dy\,p^2\,(l-|x'|)\cos kx'\,dx' \tag{5}$$

$$= \frac{\mu^2 n\,\omega\,dy}{2\pi}\left[\frac{\sin\frac{kl}{2}}{\frac{kl}{2}}\right]^2 \tag{6}$$

This function is plotted in Fig. 3. Note that the important result that, for wavelengths (λ) substantially larger than the individual particle length, the lamina pole strength noise power spectrum is flat. This "white" spectrum approximation is assumed hereafter.

OUTPUT NOISE POWER SPECTRA (NPS)

Having defined the statistics, we proceed to compute the reproduce head voltage NPS. Providing gap losses may be neglected, the reproduce head exhibits a linear voltage transfer function $4\pi V|k|\,e^{-|k|y}$. That this is true may be seen immediately since

$$\int_a^{a+d} 4\pi V|k|\,e^{-|k|y}\,dy = 4\pi V\,(1-e^{-|k|d})\,e^{-|k|a} \tag{7}$$

which is the familiar Wallace output voltage spectrum.[5] To compute the output voltage NPS, we multiply the lamina pole strength noise power spectrum by the reproduce head power transfer function and integrate through the tape thickness. This operation is, in physical terms, allowing for the fact that the reproduce head only senses a wavelength dependent, limited volume of tape adjacent to the gap.

Thus,

$$E_N^2\ (k) = \int_a^{a+d}\frac{\mu^2 n\,\omega\,dy}{2\pi}\left[4\pi V\,|k|\,e^{-|k|y}\right]^2 \tag{8}$$

$$= 4\pi\,\mu^2\,n\,\omega\,V^2\,|k|\,(1-e^{-2|k|d})\,e^{-2|k|a} \tag{9}$$

a result obtained by both Daniel[7] and Stein.[8] A similar development using the transfer function for a non-differentiating head ($4\pi\,e^{-|k|y}$) leads to the output flux NPS.

$$\Phi_N^2\ (k) = \frac{E_N^2\ (k)}{V^2\,k^2} = \frac{4\pi\,\mu^2\,n\,\omega\,(1-e^{-2|k|d})\,e^{-2|k|a}}{|k|} \tag{10}$$

Should expressions (9) and (10) be integrated over an infinite bandwidth despite the comments following equation (6), and the onset of reproduce gap losses, the results are:

$$\int_{-\infty}^{\infty} E_N^2\ (k)\,dk = 4\pi\,\mu^2\,n\,\omega\,V^2\left\{\frac{d\,(a+d/2)}{a^2\,(a+d)^2}\right\} \tag{11}$$

and

$$\int_{-\infty}^{\infty}\Phi_N^2\ (k)\,dk = 8\pi\,\mu^2\,n\,\omega\,\log_e\left(\frac{a+d}{a}\right) \tag{12}$$

as given by Mee.[6] They represent merely upper bounds to the total noise power. It will be evident that should exact results be needed they could be computed with little difficulty.

OUTPUT SIGNAL POWER SPECTRUM (SPS)

Suppose that, perhaps because of the need to minimize distortion, the sinusoidal signal magnetization recorded on the tape is only at a fraction f of the maximum amplitude possible. Further suppose, perhaps because of the need to minimize short wavelength record process losses, the tape is only recorded upon to a limited depth $d' \leq d$. Apparently by inspection of equation (7) the output signal power spectrum is:

$$E_S^2\ (k) = 1/2\left[4\pi\,\mu\,n\,\omega\,f\,V\,(1-e^{-|k|d'})\,e^{-|k|a}\right]^2 \tag{13}$$

It will be noted the head-to-tape spacing dependence of both the SPS and NPS is identical. This occurs because the same physical laws govern both signal and noise of the same frequency. The two spectra are shown in Fig. 4.

The measured signal spectrum matches the calculated curve very closely. The measured noise spectrum[7] deviates appreciably at long wavelengths from that expected. In particular, the measured noise spectrum has a lower slope than expected. This is probably because the measurements unavoidably include "surface" noise (attributable to tape roughness and consequent head-to-tape spacing variations) the magnitude of which increases with decreasing frequency. However, the differences are small when the highest quality tape is used and in any case such low frequency differences have little effect upon the wideband SNR.

NARROW-BAND SNR

The narrow-band SNR for a "slot" of width Δk is:

$$(SNR)_{narrow} = \frac{2\pi\,n\,\omega\,f^2\,(1-e^{-|k|d'})^2}{|k|\,(1-e^{-2|k|d})\,\Delta k} \tag{14}$$

It is, of course, independent of head-to-tape spacing. The adverse effects of nonsaturation and partial penetration recording are evident; both reduce the SNR because, whilst only a limited number of particles contribute to the signal, all still contribute to the noise.

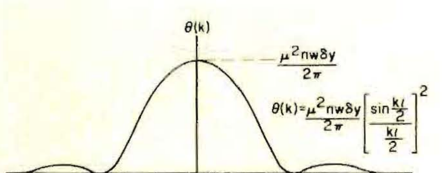

FIGURE 3. Noise power spectrum of lamina pole strength.

WIDEBAND SNR

Since the signal and noise power spectra are not identical, the wideband SNR depends upon the reproduce system equalization. Generally, wideband SNR's will also depend upon the head-to-tape spacing. A simple case, of particular interest because of its widespread use, occurs when the output signal is equalized "flat." To achieve this, the power transfer function of all parts of the reproduce system after the head must be the reciprocal of the signal power spectrum given by equation (13).

Note that this particular equalization makes the equalized noise power spectrum independent of head-to-tape spacing. An important consequence is that, in this special case, the wideband SNR is independent of reproduce head-to-tape spacing. "Out of contact" playback need not entail a loss in SNR providing other noises in the system are kept below the (attenuated) tape noise. The onus is on the system designer.

The wideband SNR for such systems is customarily defined to be the equalized signal power divided by the integrated noise power in the system bandwidth. That is,

$$(SNR)_{wide} = \left[\int_{|k|_{min}}^{|k|_{max}} \frac{(1-e^{-2|k|d})\,|k|\,d\,|k|}{2\pi\,n\,\omega\,f^2\,(1-e^{-|k|d'})^2} \right]^{-1} \qquad (15)$$

Before evaluating this expression, two simplifications may be mentioned. First, if we consider only full coating depth recording (d'= d), then, dropping the modulus signs,

$$(SNR)_{wide} = 2\pi\,n\,\omega\,f^2 \left[\int_{k_{min}}^{k_{max}} k \coth \frac{kd}{2}\,d\,k \right]^{-1} \qquad (16)$$

The signal and noise spectra for this case are shown in Fig. 5. Second, for a system in which the wavelengths over a substantial fraction of the bandwidth are comparable to or smaller than the tape coating thickness, so that kd $\gg$ 1 and coth kd/2 $\approx$ 1, then

$$(SNR)_{wide} \approx 4\pi\,n\,\omega\,f^2 \left[k^2_{max} - k^2_{min} \right]^{-1} \qquad (17)$$

This form may be compared with that resulting from the common, but erroneous, assumption that the tape noise is "white" in which case SNR α $(k_{max}-k_{min})^{-1}$. In a system equalized flat, the NPS rises at approximately 3 dB/octave, and consequently doubling the bandwidth actually entails a loss in SNR of about 6 dB rather than 3 dB.

It will be shown below that the extremely simple form of equation (17) does indeed closely approximate measured SNR's. It should be noted that the tape speed (V), the head-to-tape spacing (a), the coating thickness (d) and the dipole moment (μ) do not appear;

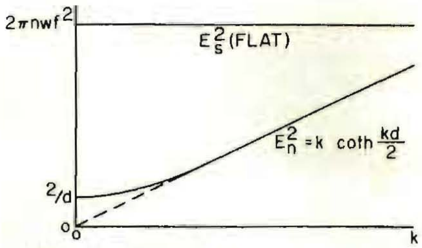

FIGURE 5. Signal and noise power spectra versus wavenumber (k) in a system equalized flat. The depth of recording is equal to the coating thickness. Both spectra have been multiplied by a factor of $2\pi n \omega f^2$.

they do not have an important effect upon the maximum SNR.

The best tapes obviously yield the highest product of nf^2. Magnetostatic interparticle interactions, which are rather poorly understood, control the distortion limit (f) and consequently n and f are not independent variables. No simple theory giving the functional dependence of f on n can presently be given.

NUMERICAL EXAMPLES

We consider first the case of a 400-Hz to 1.5-MHz 120-ips, 50-mil trackwidth, wideband analog recorder equalized flat. The record gap length (150 μin) used is known to be noncritical, since the adjustments of the input currents largely compensate for differing gap lengths. Both the reproduce gap length (25 μin) and the average γ-Fe_2O_3 particle length (about 20 μin) are much smaller than the minimum wavelengths occurring (80 μin). A-c bias is used at a level which yields the maximum short wavelength output. If a head-to-tape spacing of 20 μin is assumed, the unequalized signal spectrum matches that expected for a partial penetration depth of about 75 to 100 μin. The signal input level is adjusted so that no more than 1% third harmonic distortion exists at long wavelengths. Under similar conditions, the RMS remanent flux in audio tapes has been found to be about 200 nano-weber per meter of track width which is equivalent to a peak magnetization of about 250 gauss.[8] Since the maximum remanence of γ-Fe_2O_3 analog tapes is about 1250 gauss, the distortion limit (f) is taken to be 0.2. The tape (Ampex 771) of coating thickness 400 μin, contains acicular γ-Fe_2O_3 particles of dimensions 20 x 4 x 4 μin (i.e., 5000 x 1000 x 1000 Å) which are packed at one-third by volume. The number of particles per cubic microinch (n) is therefore about 10^{-3}.

The exact SNR given in equation (15) may be written:

$$(SNR)_{wide} \approx 2\pi\,n\,\omega\,f^2 \left[\frac{1}{d^2} \int_0^u \frac{s(1-e^{-2s})\,d\,s}{(1-e^{-\alpha s})^2} \right]^{-1} \qquad (18)$$

where u = k_{max} d, and α = d'/d

In the present case, substituting numbers,

$$(SNR)_{wide} \approx 2.10^6 \left[\int_0^u \frac{s(1-e^{-2s})\,d\,s}{(1-e^{-\alpha s})^2} \right]^{-1} \qquad (19)$$

$$\text{with } u = \frac{2\pi\,d}{\lambda_{min}} \approx 30, \text{ and } \alpha = 0.4$$

The integral has been evaluated numerically and the results are tabulated in Table 1. Consequently, equation (19) may be written

$$10 \log_{10} (SNR)_{wide} = 10 \log_{10} (2.10^6) - 26.6$$
$$= 63 - 26.6 = 36.4 \text{ dB}$$

The simple approximate form given in equation (17) yields

$$10 \log_{10} (SNR)_{wide} = 10 \log_{10} (4\pi\,n\omega f^2\,k_{max}^{-2})$$
$$= 10 \log_{10} (4000) = 36 \text{ dB}$$

Table I $\quad 10 \log_{10} \int_0^u \frac{s(1-e^{-2s})\,d\,s}{(1-e^{-\alpha s})^2}$

for some values of u and α

u	α 0.2	0.4	0.6	0.8	1.0
5	20.0	15.5	13.6	12.5	12.0
10	22.1	18.9	17.9	17.5	17.3
20	25.2	23.6	23.3	23.1	23.1
40	29.7	29.2	29.1	29.1	29.0
80	35.2	35.1	35.1	35.1	35.1
160	41.1	41.1	41.1	41.1	41.1

which is less than 1 dB different from the exact result. Experimentally, if due care is taken to minimize other noises (mainly those due to reproduce head eddy currents) and to maintain the head efficiency at the upper frequencies, wideband RMS signal-to-RMS noise ratios of 34 to 35 dB have been measured in excellent agreement with the above theory.

As a second example we consider briefly a 40-Hz to 15 KHz, 7.5-ips, 80-mil trackwidth, professional audio recorder. Such machines use both variable pre-equalization (of the record current) and fixed post-equalization, whereas the above theory considers only variable post-equalization.

It might seem, therefore, that the theory is not directly applicable. However, it turns out that direct application of equations (15) and (17) in fact does yield "good" numbers when the tape speed is greater than or equal to 7.5 ips. This coincidence is related to the following considerations: the better quality tapes need little pre-equalization and thus produce an output spectrum close to that given by equation (7); the poorer tapes have considerable pre-equalization applied but again they yield the same output spectrum; and the fact that there is not much difference between the noise spectra of the different tapes.

To proceed with the calculation then we note that whereas the distortion limit is the same as in the previous example, now the

depth of recording is equal to the standard γ-Fe_2O_3 coating thickness (400 μin). In this case ($u = 5$, $\alpha = 1.0$) equations (15) and (17) yield 10 log $(SNR)_{wide}$ values of 54 and 55 dB respectively, which values compare favorably with the 56 to 57 dB usually measured on such "half-track" audio machines.

The uncertain factors in these calculations are, of course, the partial penetration depth (d') and the distortion factor (f). Whereas the calculated $(SNR)_{wide}$ is not sensitively dependent upon the exact value of the penetration depth, it does depend critically upon the distortion factor used. The value adopted here (0.2) is believed to be quite accurate and typical of modern analog tapes. However, even if the distortion factor is regarded simply as an adjustable parameter, the valuable fact remains that the theory, with $f = 0.2$, yields results in such excellent agreement with practice.

The above theory does not consider the effects of magnetostatic interactions which, particularly in non-uniformly packed tapes, will give rise to modulation noise. The excellent agreements found using the above simple theory indicate, however, that, at least in the case of distortion limited recorders where, perforce, the signal level and tape magnetization is low, the effect of modulation noise upon $(SNR)_{wide}$ is small.

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Nomenclature:

A	cross sectional area of tape (normal to head-tape motion)
a	head-to-tape spacing
b	dimensionless factor equal to ± 1
d	tape coating thickness
d'	depth of recording ($d' \leq d$)
E_N	reproduce head noise voltage (k domain)
E_S	reproduce head signal voltage (k domain)
f	ratio of signal to maximum possible signal
k	wavenumber ($2\pi/\lambda$)
k_{min}	minimum wavenumber
k_{max}	maximum wavenumber
l	magnetic particle length
M	tape lamina longitudinal magnetization (x domain)
n	number of particles per unit volume
p	magnetic particle pole strength (x domain)
P	tape lamina pole strength (x domain)
S	dimensionless factor (kd)
u	dimensionless factor (k_{max} d)
V	head-to-tape relative velocity
ω	track width
x	tape longitudinal coordinate
x'	offset tape coordinate
y	tape normal coordinate
α	dimensionless factor (d'/d)
λ	wavelength
μ	magnetic particle dipole moment (pl)
Θ	lamina pole strength noise power (k domain)

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Volume 8 Number 5
A magazine of Ampex Corporation

The drawing pictured on the front page is of the first magnetic recorder—the Telegraphone. The inventor, Valdemar Poulsen, received a U.S. patent approval for his "device for effecting the storing up of speech or signals by magnetically influencing magnetizable bodies" on November 13, 1900.

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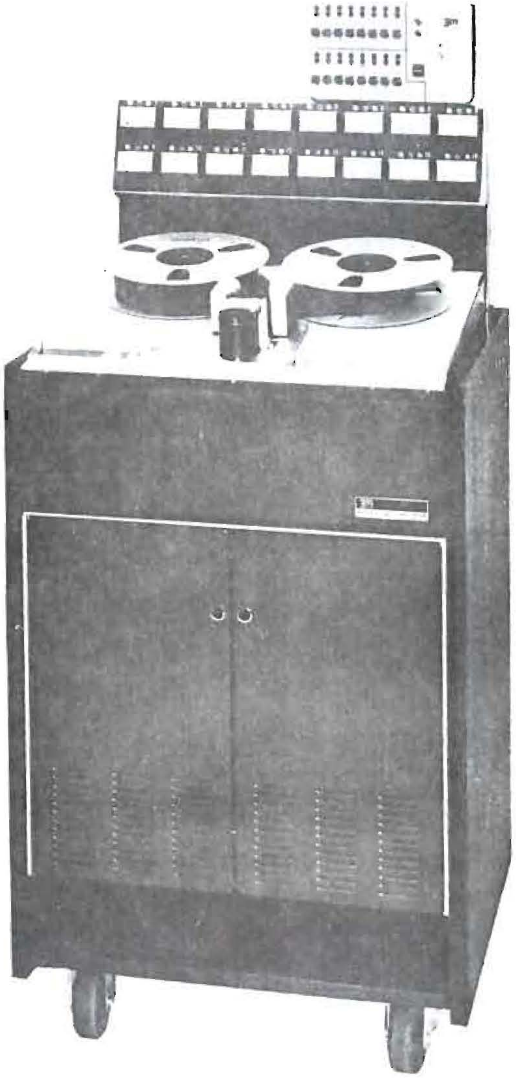

Figure 1. 3M Brand Professional Audio Recorder

FOR SALES INFORMATION

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Camarillo, California 93010
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EASTERN U. S.

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GENERAL DESCRIPTION

GENERAL

The 3M Brand Series 500 Professional Audio Recorder (Part No. 56000A000) is manufactured by the Mincom Division of the 3M Company in Camarillo, California.

FUNCTION

The recorder fulfills a requirement in the professional recording industry for a versatile, multichannel, compact magnetic tape recorder for producing superior quality master recording tapes. The recorder features up to 16 track record/reproduce performance with full remote control operation, including synchronous overdub. The patented Isoloop tape drive system has been incorporated in a 2 inch tape transport which provides the Series 500 line of recorders all the flexibility, ease of threading, and tape handling performance enjoyed by other 3M Brand Professional Audio Recorders. A new standard of timing accuracy has been attained in the Series 500 tape transports as a result of an entirely new capstan drive design.

Coupled with these features, the recorder incorporates packaging concepts providing greatly improved accessibility of components for alignment and maintenance purposes. The exclusive use of silicon solid-state devices throughout the electronic circuits of the Series 500 recorders provide greater stability and long-term reliability.

EQUIPMENT DESCRIPTION

Three tape recorder configurations are available in the 3M Brand 500 Series: 1) a 16 track version; 2) an 8 track version; 3) an 8 track convertible version, capable of conversion to a 16 track system by inserting additional plug-in circuit cards and replacing the 8 track heads with 16 track heads.

Physically, each version consists of a tape transport pivot mounted in the top of rectangular plastic-laminated wood console (see figure 1). Below the transport is a signal electronics module assembly containing the record/playback electronics and operating mode switching circuits. A meter display panel mounted above the transport provides selective input/output signal monitoring of each channel. The system is completed by the addition of a self-contained solid-state power supply fastened to the floor of the console and a remote control unit which is detachable from its mounting position on top of the meter panel, allowing the recorder to be operated up to 25 feet from the console.

Tape Transport

A 2 inch tape transport is used in the 16 track and 8 track convertible versions of the Series 500 recorders (see figure 2). The tape guides on the transport are adjustable to accommodate either 1 or 2 inch tape. A 1 inch transport is provided with the 8 track version. The transport will accommodate 10-1/2 inch diameter NAB reels for the 1 inch width tape (8 track version), and semi-precision video tape reels when using 2 inch width tape (16 track version). The tape transport operates at either of two electrically selectable tape speeds. The most common speeds are 7-1/2 and 15 ips; however, other speeds are available (see table 1).

The tape transport contains the tape motion and tape handling controls; plus, it performs certain electrical command functions common to each channel of the record/reproduce electronics. The POWER button on the transport controls power to the entire system.

Isoloop Tape Drive

The tape transport mechanism of the 3M Brand Professional Audio Recorder is derived from designs used in instrumentation recorders, where standards of timing accuracy and wow and flutter are even more demanding than they are in audio recording. The heart of the patented Isoloop tape drive is the differential capstan, which maintains a constant tape tension within the drive and positive contact of the

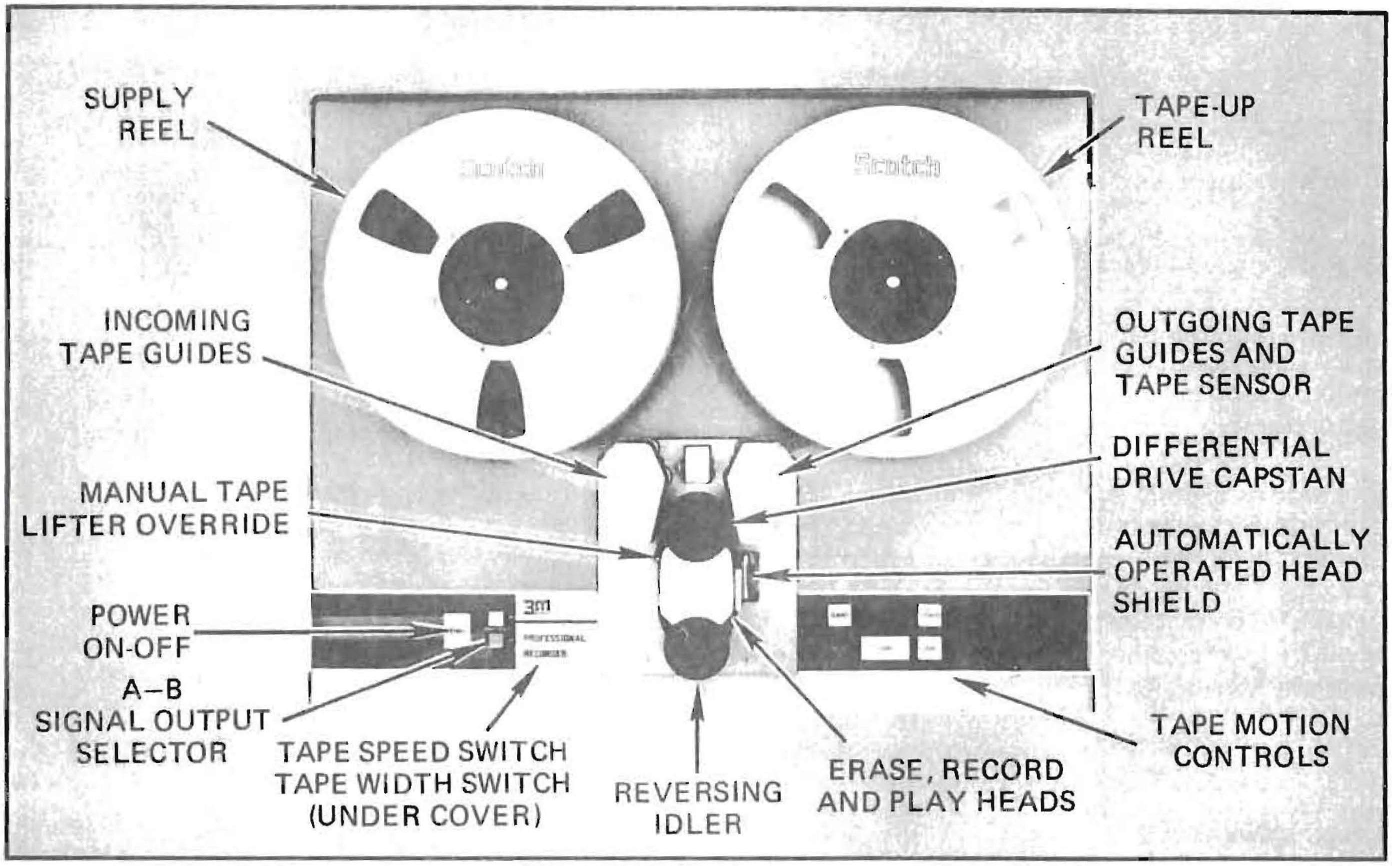

Figure 2. Tape Transport

Table 1. List of Components

Component	Description
TAPE TRANSPORT	
BASIC TAPE TRANSPORT 56013B100-1	Consists of basic 2 inch tape transport equipped for 7.5 and 15 ips, 60 Hz power. Less head assemblies and mounting hardware.
56013B100-2	Same as 56013B100-1 but equipped with 7.5 and 15 ips, 50 Hz capstan motor.
56013B100-3	Same as 56013B100-1 but equipped with 15 and 30 ips, 60 Hz capstan motor.
56013B100-4	Same as 56013B100-1 but equipped with 15 and 30 ips, 50 Hz capstan motor.

Table 1. List of Components (Cont.)

Component	Description
TAPE TRANSPORT (Cont.)	
TAPE SPEED KIT (Capstan Motor) Speed (ips) Power (Hz) 56013A910-1 15–30 60 56013A910-2 7.5–15 50 56013A910-3 15–30 50 56013A910-4 7.5–15 60	Consists of capstan motor assembly, including capacitor and connector.
HEAD ASSEMBLIES 56119A100 (8 Track) 56119A100 (16 Track)	Includes playback head door shield, and erase, record, and playback head stacks mounted on bolt-on precision plate, with connectors.
RECORD/REPRODUCE ELECTRONICS	
ELECTRONIC MODULE ASSY 56059B100-1 (16 Track) 56059B100-2 (8 Track)	Consists of the basic electronics chassis less all plug-in printed circuit boards
ELECTRONIC ASSEMBLY (PC) BOARDS	These boards may be obtained individually or in sets to accommodate either the 8 or 16 track machine versions.
16 CHANNEL BOARD SET 56059A900	Consists of 64 plug-in printed circuit boards and one extender board.
8 CHANNEL BOARD SET 56059A910	Consists of 32 plug-in printed circuit boards and one extender board.
INDIVIDUAL BOARDS:	One each of four boards required for each channel of record and reproduce.
BIAS AND ERASE BOARD (1) 23059B020	Part of the record circuit.
RECORD AMPLIFIER BOARD (4) 23059B040	Part of the record circuit.
LINE DRIVER AMPLIFIER BOARD (6) 23059A060	Part of the reproduce circuit.
PREAMPLIFIER WITH OVERDUB BOARD (7/9) 23059B090	Part of the reproduce circuit.

Table 1. List of Components (Cont.)

Component	Description
RECORD/REPRODUCE ELECTRONICS (Cont.)	
EXTENDER BOARD 23059A110	Used as an aid in troubleshooting; allows circuit board to operate in an extended position outside its slot, providing access to both sides of the board.
METER PANEL ASSEMBLY 56038A100-1 (16 Track) 56038A100-2 (8 Track)	Consists of 8 or 16 VU meters panel mounted as well as their associated monitor select switches and indicator lamps with interconnecting cable and connector.
REMOTE CONTROL ASSEMBLY 56017A100-1 (16 Track) 56017A100-2 (8 Track)	Consists of a control box with a 25 foot cable and connector containing controls and indicators appropriate for providing remote control of either an 8 or 16 track recorder.
POWER SUPPLY ASSEMBLY 56031A900	Consists of a 28 volts dc regulated power supply with cable and connector assembly.

tape against the heads (see figure 3). In addition, the unsupported tape path is extremely short in comparison to standard design tape recorders. This short path reduces longitudinal oscillation to a new low and eliminates the need for a series of tape guides to maintain a proper tape path.

The tape tension required to minimize flutter and hold the tape against the heads is generated within the closed loop by the differential drive capstan. The tape drive surface of the capstan is divided into regions of two different diameters. The incoming idler roller is contoured so as to press the tape firmly into the matching "grooves" (of the smaller diameter) of the capstan. The outgoing idler roller is shaped so as to press the tape firmly against the "ridges" (of the larger diameter) of the capstan. This differential of capstan diameters constantly tries to extract more tape than is being fed into the loop and creates the necessary tension due to the slight elasticity of the tape itself. This tape tension is always kept safely within its elastic limits.

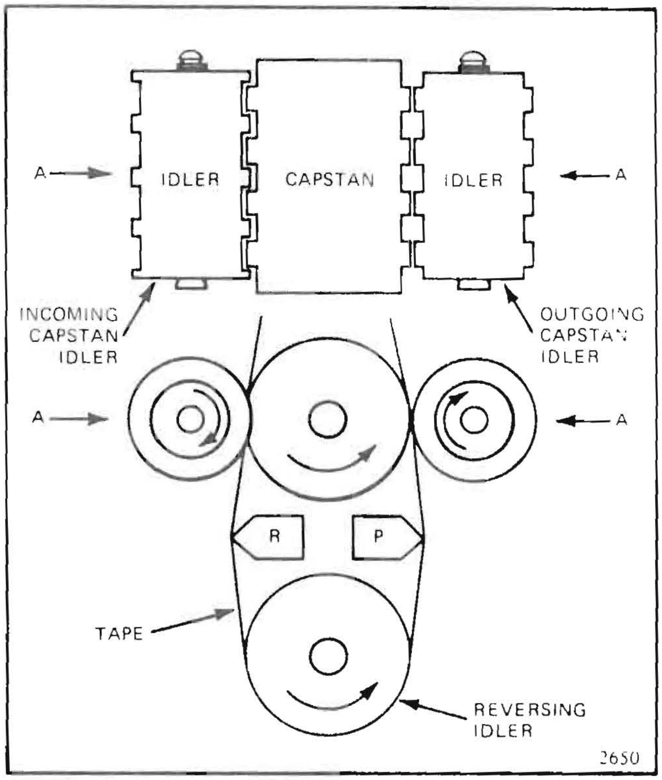

Figure 3. Isoloop Tape Drive

Signal Electronics Assembly

The signal electronics assembly located below the tape transport (see figure 4) consists of three rows of printed circuit plug-in boards and two rows of adjustment controls. The top and bottom rows of the 16 track or 8 track convertible versions will accept 24 boards each; eight channels of record and reproduce boards are grouped in each row by track sequence rather than function, in order to provide a more logical means of locating the circuit boards associated with each channel. The center row contains either 8 or 16 tracks of bias/erase amplifier boards, as required by the machine configuration.

In the two open spaces between the rows of plug-in boards are the control components which consist of three plug-in relays per track for record, sync, and input/output monitor select; two potentiometers for RECORD LEVEL control and SYNC LEVEL calibration; and two plug-in transistors for the relay logic circuits. The erase current adjustment controls and erase current monitoring jacks are also located in the center row.

The signal electronics assembly is accessible through two doors on the front of the console, allowing access to all of the circuit boards, adjustments, and control components. The input and output signal connectors, function control input connector, meter monitoring output connector, and input (dc) power connector are located on the rear of the signal electronics assembly which is accessible from the rear of the console.

Display Panel

The 16 track and 8 track convertible recorder configured versions contain 16 VU meters mounted on the display panel. See figure 7. Each meter is numbered for channel identification. Above each meter are two lamps which indicate the signal being monitored, input A or output B, and a selector switch which allows the selection of the signal monitored on the meter, A or B.

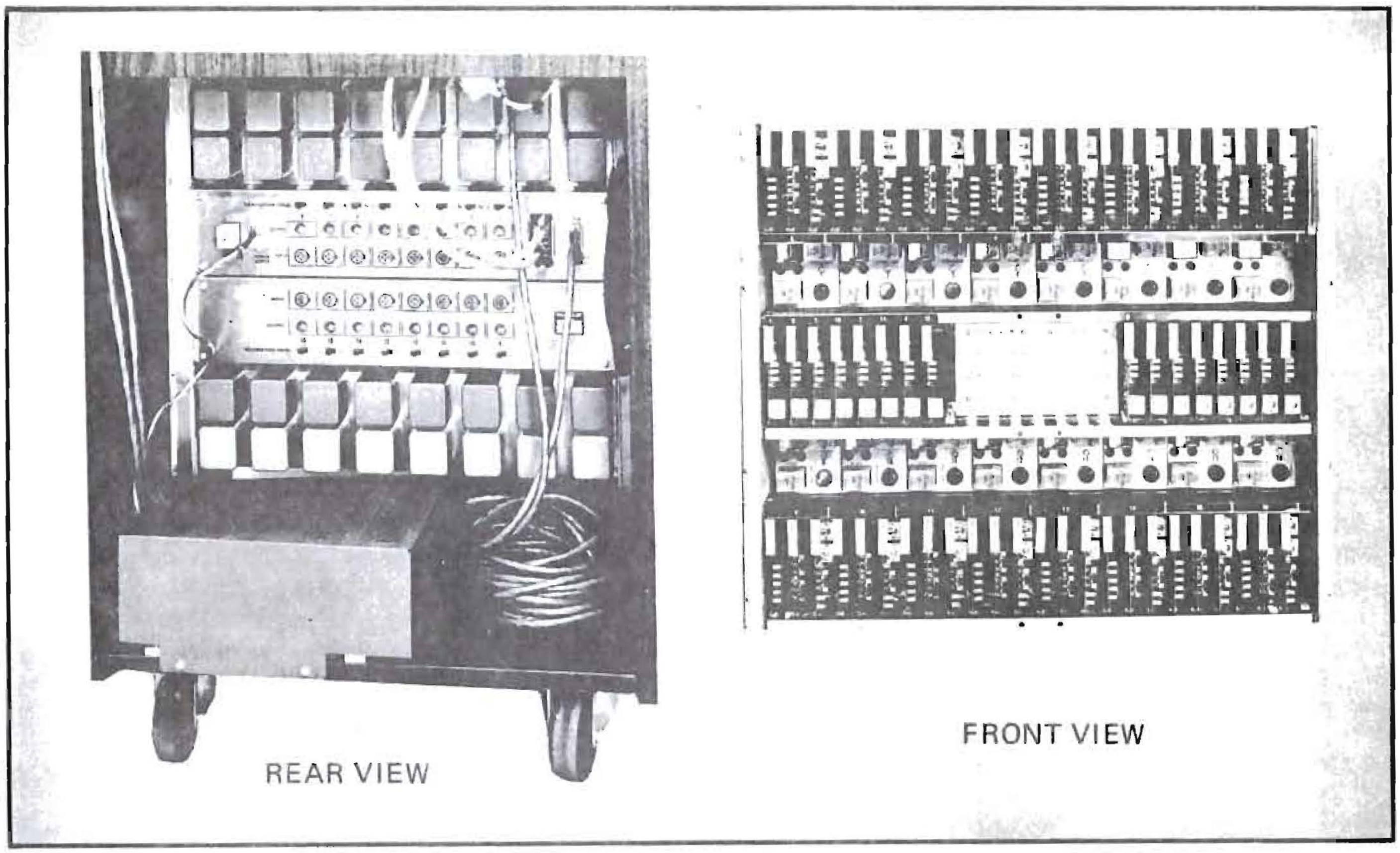

Figure 4. Signal Electronics Assembly

Remote Control

The remote control box, figure 8, is divided into two groups of controls and indicators. The right-hand group of back lighted pushbutton control switches are common to the tape motion controls on the transport and provide identical control at a remote location when desired. A tape RUNOUT indicator lamp is also included in this group, along with two pushbutton switches that provide simultaneous transfer of the output monitor function (A or B) of all channels. The output monitor switches are also common to identical switches on the transport. The left-hand group of switches are common to the remote control box only, and allow the mode of operation of each channel to be preselected to fit the need of any particular technique of recording desired. Sixteen 3-position lever switches accomplish this function, allowing the selection of any one of three modes of operation (READY-SAFE-SYNC) for each channel. In addition to these switches, a Program Select switch is provided which allows two modes of logic (NORM/CUE) when cuing up on a prerecorded sync track.

Power Supply

The record/reproduce electronics and their associated control circuits are energized by a common solid-state regulated power supply fastened to the floor of the console.

SPECIFICATIONS

Specifications for the 3M Brand Professional Tape Recorder are presented in table 2. These specifications are based upon operation and maintenance in accordance with the procedures and conditions presented in this manual. Deviation from these procedures, use of other than recommended magnetic tapes, or modification of the equipment may result in degradation of the equipment performance. These specifications are subject to change without notice.

Table 2. Specifications

Characteristics	Specifications			
GENERAL				
Power Requirements	115 ±10 volts single phase, 60 Hz nominal.			
	Transport:	500 watts maximum.		
	Signal Electronics:	200 watts maximum (8 track) 400 watts maximum (16 track)		
	Alternate input power provisions			
	Transport:	May be operated at 115 ±10 volts single phase, 50 Hz with tape speed kits 56013A910-2 or 56013A910-3 (50 Hz capstan drive motor kits).		
Size and Weight		Height	Width	Depth
	Operating configuration	53¾ in.	27 in.	22½ in.
	Shipping configuration	43 in.	27 in.	22½ in.
	Weight	304 lbs (16 track) 256 lbs. (8 track convertible) 241 lbs. (8 track only)		

Table 2. Specifications (Cont.)

Characteristics	Specifications
GENERAL (Cont.)	
	Remote Control — 6½ lbs. (16 track with 25 foot cables and connectors) 4¾ lbs. (8 track with 25 foot cables and connectors)
TRANSPORT	
Tape Speeds	Each transport is provided with two electrically switchable tape speeds. Standard machines are equipped for 7½ and 15 ips. 15 and 30 ips speeds are available on special order.
Speed Accuracy	±0.10% measured relative to line frequency. Specification does not include line frequency variations.
Tape Width	1 or 2 inch.
Reel Size	1 inch tape: Standard 10½ inch reel with NAB hub. 2 inch tape: 10½ inch semiprecision video type reel.
Recording Time	2400 ft. tape 60 minutes at 7½ ips 30 minutes at 15 ips 15 minutes at 30 ips
Start Time	1.0 second maximum in play or record mode at 15 ips.
Stopping Time	1.0 second from play or record mode.
Rewind Time	1¾ minutes for 2400 feet.
Flutter	<u>Speed (ips)</u> / <u>Flutter Band (Hz)</u> / <u>Maximum % Flutter (rms)</u> 15 / 0.5 to 200 / 0.06 15 / 0.5 to 5000 / 0.08 7½ / 0.5 to 200 / 0.13 7½ / 0.5 to 5000 / 0.16 All measurements of flutter are made by recording a tone on the machine under test, rewinding the tape, and measuring the flutter on replay. The maximum additive phase case is accepted as maximum flutter.
Isoloop Drive	A closed loop positive drive, universal capstan, pinch rollers, and reversing idler for 1 and 2 inch tape. Tape guides are adjustable for 1 or 2 inch tape.

Table 2. Specifications (Cont.)

Characteristics	Specifications
TRANSPORT (Cont.)	
Operating Controls	Two control groups on the transport control system operation. Group I — Located on lower left corner of transport: Power: On/Off (backlighted pushbutton) Speed: High/Low (slide switch) Tape Width: Wide/Narrow (slide switch) Group II — Located on lower right corner of transport: Backlighted pushbuttons for -- PLAY FORWARD RECORD* REWIND STOP All controls are electrically interlocked to prevent possible damage to tape or transport due to operator error. *PLAY and RECORD button must be pressed at the same time to place the transport and associated signal electronics in the record mode of operation.
Braking	Dynamic braking is provided from all modes to stop.
Tape Sensing	Photocell sensor stops transport motion when tape runout or tape breakage occurs.
SIGNAL ELECTRONICS	
Tape Type	Specifications herein are based on the use of Scotch Brand Dynarange magnetic recording tapes, Type 202 or 203.
Equalization	Each signal electronics channel contains two (2) speed adjustable equalization networks. Transfer of equalization networks are automatic when transport tape speed is changed. Normally, machines are equalized for NAB 7½ and 15 ips speeds. Other speeds and forms of equalization are available on special order.
Bias and Erase Oscillator	A master oscillator on the tape transport supplies 120 kHz through a low impedance bus to individual bias and erase amplifiers for each channel.
Phasing	Signal input to output phase is held to less than 90° on all channels.

Table 2. Specifications (Cont.)

Characteristics	Specifications
SIGNAL ELECTRONICS (Cont.)	
Channel Separation	Channel-to-channel crosstalk separation is greater than 50 dB at 500 Hz (zero VU).
Degree of Erasure	A 1 kHz signal at 3% distortion level is reduced 72 dB or more by the erase head provided for NAB standard operation.
Input Impedance	20,000 ohm balanced or unbalanced line. -10 dBm to +8 dBm signal on 600 ohm line.
Output Impedance	600 ohm terminated or unterminated by selector switch. 150 ohm output tap is provided on the output transformer. Nominal line level +4 dBm.
Frequency Response (Record/Reproduce)	15 ips NAB Equalization ±2 dB 100 Hz to 15 kHz $^{+2}_{-3}$ dB 50 to 99 Hz $^{+2}_{-4}$ dB 30 to 49 Hz 7½ ips NAB Equalization ±2 dB 100 Hz to 10 kHz $^{+2}_{-3}$ dB 50 to 99 Hz $^{+2}_{-4}$ dB 30 to 49 Hz
Signal-to-Noise Ratio	For standard 8 or 16 track NAB equalized recording systems, the S/N ratio is maintained at 65 dB, or greater, with a machine speed of 15 ips. S/N ratio is measured with reference to the level of 6 dB above the 700 Hz reference signal on a standard NAB alignment tape.
Harmonic Distortion	Distortion reduction circuits hold total harmonic distortion to less than 1.0 percent at input signal levels up to 6 dB above the 700 Hz reference signal on a standard NAB alignment tape.
Monitoring	The input or output signal of each channel is displayed on a 2½ inch VU meter.

Table 2. Specifications (Cont.)

Characteristics	Specifications
SIGNAL ELECTRONICS (Cont.)	
Operating Controls	Remote Control Box: Tape Motion Controls (identical function with controls on tape transport). Output Select Pushbuttons A -B (identical function with controls on tape transport). Mode Select switches, READY-SAFE-SYNC (one 3-position switch for each channel). Program Select switch, NORM-CUE. Electronic Module Assembly: Input Level (one for each channel) Meter Panel: A B Monitor Select switches (one for each channel).

TECHNICAL DESCRIPTION

INTRODUCTION

The 3M Brand, Series 500 recorders consist basically of a tape transport and the required record and reproduce electronics with their associated control circuits. The signal to be recorded is amplified and applied to a magnetic record head which impresses a magnetic pattern in the oxide coating of the magnetic recording tape in accordance with the variations of the input signal. During reproduction, the variations in magnetic flux that were impressed on the tape during recording are sensed by a reproduce head, amplified, and applied to the recorder output and monitoring circuits.

In order to record and reproduce with a minimum of distortion, a high-frequency bias is mixed with the input signal at the record head so that recording takes place in the portion of the magnetization curve that is essentially linear. The signal recovered by the reproduce head must also be equalized by circuits that compensate for the response characteristics of the reproduce head at low and high frequencies.

The high-frequency signal that is used for bias is also used to erase signals that may have previously been recorded on the tape. The erase signal is applied to a separate erase head, which is similar to the record head but applies the high-frequency signal at a much higher level. The signal applied to the erase head drives the magnetic material of the tape to complete magnetic saturation to obliterate any signal or noise that may have been previously recorded on the tape. Then, as the tape moves out of the saturating field, alternate field oscillations result in completely degaussed tape.

The Isoloop tape drive maintains differential tension within the loop of tape passing over the heads and ensures that the tape remains in close contact with the heads during tape travel. This ensures that the magnetic flux impressed by the record head penetrates the oxide material uniformly and eliminates variations in amplitude that can result if the close head-to-tape contact is not maintained. Similar amplitude variations can take place if the tape is not maintained in close contact with the play head.

TAPE TRANSPORT MECHANICAL FUNCTIONS

Figure 20 illustrates the basic mechanical operation of the tape transport. When tape is placed in the Isoloop drive path as shown, the tape transport motion control logic circuits (to be covered later) are automatically activated by the photoelectric tape sensor, placing the transport in the standby condition. Operation of the transport is then accomplished by pressing the desired tape motion control switch either on the transport panel or at the remote control box. Each tape motion control switch operates through a system of safety interlock relays that allows any button to be pressed in any sequence at any time with complete safety to the tape and machine.

Components of the tape drive system (see figure 21) consist of a capstan drive motor, two reel drive motors, and control relays that determine the mode of operation. When in play and record modes, the tape is moved through the Isoloop by the capstan. The reel drive motors maintain constant tension on the tape as it enters and leaves the loop. When in fast-forward or rewind, the capstan motor is stopped, tension is released within the Isoloop, and the reel drive motors move the tape through the loop independently of the capstan. Before entering and after leaving the Isoloop, the tape passes over guides to ensure that the tape is properly aligned with the magnetic heads.

When the transport is placed in the play or record mode, the capstan motor starts, the solenoids press the capstan idlers against the tape, clamping it to the capstan to prevent it from slipping. The tape is moved past the incoming idler and capstan, past the erase and record heads, and around the reversing idler. From the reversing idler, it passes the play head, and the outgoing idler and capstan. During fast-forward and rewind, solenoid-actuated tape lifters hold the tape away from the heads so that signals on the tape will not be played back which would cause an annoying squeal. The tape lifters are inactive in the play, record, and stop modes. The tape lifter may be manually overridden by pressing the tape lifter override lever. This restores the tape against the head so that it may be heard.

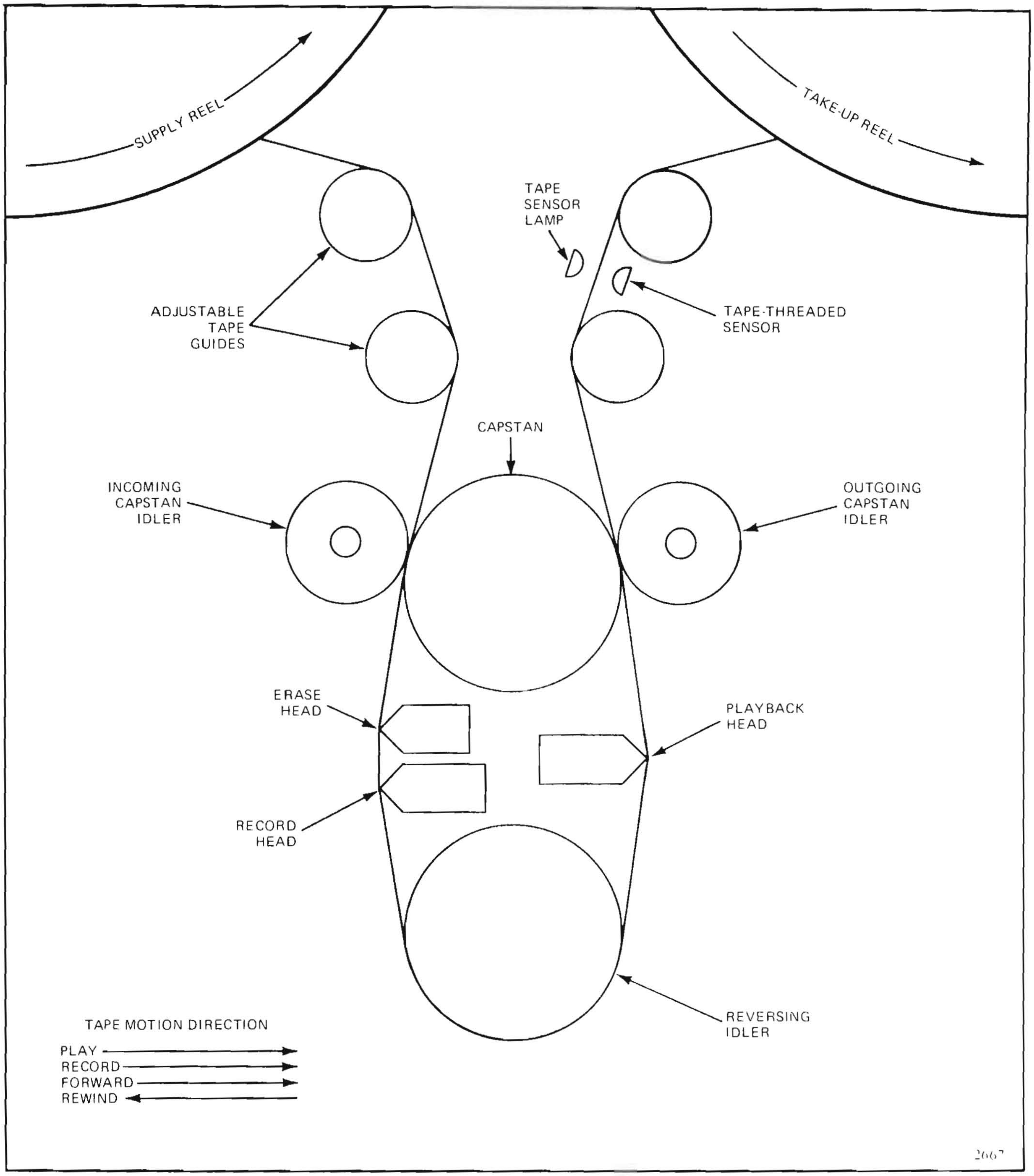

Figure 20. Tape Transport, Block Diagram

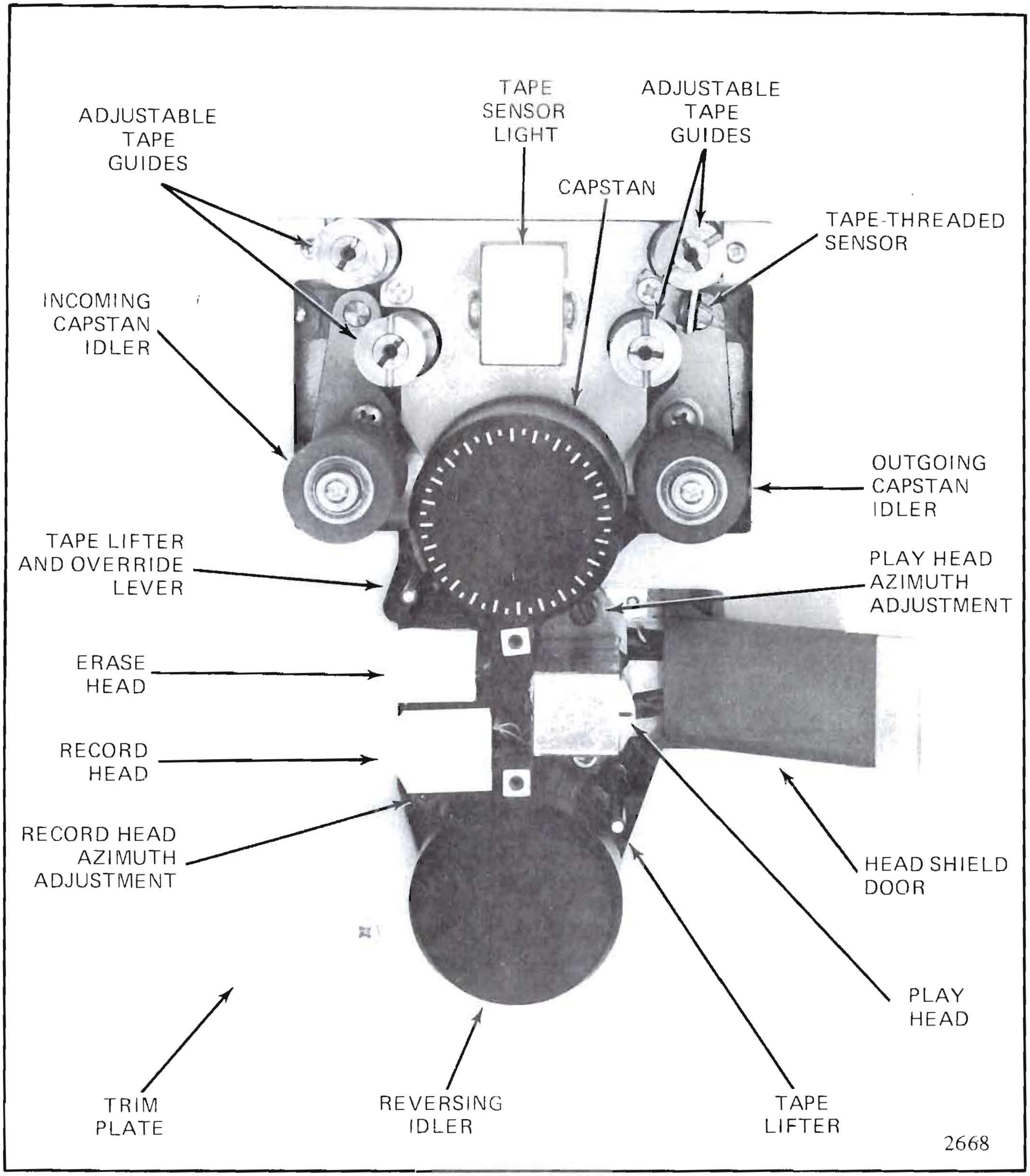

Figure 21. Tape Drive Components

The play head is enclosed in a magnetic shield to avoid pick up of noise from surrounding equipment and bias-frequency energy radiated by the erase and record heads. A solenoid-actuated cover is positioned over the tape as it passes the play head and serves to complete the shielding of the head. During fast-forward, rewind, and stop, the hinged cover is moved away from the head to allow the tape to be lifted by the tape lifters and allows easy threading of the tape. The cover is closed during play and record.

TAPE TRANSPORT CIRCUIT DESCRIPTION

Figure 23 in the schematic section should be used as a reference throughout the following discussions of the tape transport circuits.

Power Circuits

The POWER switch, S6, when operated, closes both sides of the AC input power line activating a number of circuits. These are as follows:

1. Bridge rectifier CR46 through CR49 charges capacitor C65 through R60 to approximately 165 volts in the absence of a load. This voltage is applied through J7-2 and J9-1 to the fields of the take-up and rewind motors. Field returns are through J7-1, and J9-2 through J6-4, and K1 contacts 6 and 10. Relay K1 operates as soon as power is turned on, unless the transport has been previously threaded with tape.

2. AC power is supplied to the electronic assembly power supply through pins 11 and 12 of connector J4.

3. Power is supplied to step-down transformer T60 through connector pins 1 and 2 of J13. The low-voltage secondary feeds a full-wave bridge rectifier, consisting of CR37 through CR40, which supplies DC power through terminals J5-5 to C66 and series regulator transistor Q60. Zener Diode CR50 is supplied from R14 and establishes a voltage reference of 27 volts, applied through R15 to the base of amplifier transistor Q1. The collector of Q1 is directly coupled to the base of Q60 and the output collector potential of Q60 establishes the emitter voltage of Q1. The two transistors thus act to regulate the bus potential (approximately 26.5 volts). When power is applied, the bus potential lights POWER indicator DS6 and tape sensing lamp DS8. If fail-safe brakes are furnished, this voltage causes them to be released. Without tape on the machine, light from DS8 falls on photo sensor V60. The base of Q61 is thereby held near ground potential. The collector at Q61 is then at a relatively high potential, causing Q62 to increase conduction. Current flows through Q62 to relay K1 through J6-7 to operate relay K1. Through K1 contacts 12 and 8, voltage is applied through J6-9 to J3-N to light the RUNOUT indicator lamp on the remote control box, indicating that the machine is on but inoperative due to the absence of threaded tape. The playback head shield cover door is caused to open through CR-25, J6-14, to solenoid L4, with a return path through TB1-1. Also at this time, K1 contacts 11 and 3 and 12 and 4 are open, and the 27 volt bus can perform no further function. Because of this, the machine may not be put into any mode of operation until tape is threaded on the machine.

4. The blower fan B1 operates when the POWER switch S6 is closed, AC power being supplied to the fan motor through TB1-5 and TB1-6.

Tape Threaded Condition

When tape is threaded through the Isoloop, light from DS8 is blocked by the tape, causing the resistance of V60 to rise. This action causes Q61 to conduct, cutting Q62 off, releasing K1. CR1 provides surge protection.

When K1 contacts 12 and 8 open, the head shield cover remains open because S12 is closed whenever it is in the open position. This applies power through J6-M, CR26, and P6-14 activating L4 which holds the cover in the open position. However, the opening of K1 contacts 12 and 8 removes 28 volt power from P6-9, extinguishing the tape RUNOUT lamp on the remote control box.

Closure of K1 contacts 11 and 3 and 12 and 4 applies 28 volt power through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3, and K5 contacts 12 and 4 through J5-14 to light STOP lamp DS3; and a path through CR13 and R5 charges C3.

and operates K4. Opening of K1 contacts 10 and 6 inserts R9 in the return path of the reel motor fields. The voltage developed across this resistor is applied through K5 contacts 1 and 9, K6 contacts 1 and 9, K7 contacts 1 and 9 through J6-A to the armature of the rewind motor. A similar path applies the same voltage to the take-up motor through K5 contacts 2 and 10, K6 contacts 2 and 10, K7 contacts 2 and 10, and J6-2. The polarity of the voltage and the armature terminals used in connecting the reel motors cause them to turn in opposite directions. The torque generated is small but sufficient to remove any slack in the tape threaded through the Isoloop. With the tape now threaded and the STOP lamp illuminated, the transport is ready to be put into motion from its standby condition.

From Standstill To Play

28 volt power is present at PLAY switch S5 through J6-D, J2-9, and J2-10. Pressing the PLAY push-button applies power through J6-18 and CR4 to operate relay K3 momentarily. Through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3, K101 contacts 1 and 9, and K3 contacts 8 and 12, K5 is activated. The power activating K5 is also applied through P6-17 to PLAY indicator lamp DS5, and capstan idler solenoids L1 and L2, which press the tape against the capstan. AC power is applied to the capstan motor through K5 contacts 7 and 11, K1 contacts 1 and 9, P5-D, J11-2, switch S8, and through plug P8 to the capstan motor.

Prior to the operation of K5, relay K4 is operated, and capacitor C3 is charged through R5, CR13, and K5 contacts 4 and 12. Upon operation of K5, power is transferred from contact 4 to contact 8 of K5. The transfer of power to contact 8 provides the necessary holding power to maintain K5 operative when the initial path through K3, and K101 is broken. The breaking of contacts 12 and 4 when K5 operates removes power from the STOP lamp DS3 and relay K4; however, K4 does not release immediately due to the charge on C3, but K4 remains operative for approximately 0.5 second.

When K5 operates, full dc power is applied through K4 contacts 6 and 10, K5 contacts 6 and 10, K6 contacts 2 and 10, and K7 contacts 2 and 10 to the take-up motor armature. Reasonably high hold-back torque to the supply motor is obtained through K4 contacts 6 and 10, R8, K5 contacts 5 and 9, K6 contacts 1 and 9, and K7 contacts 1 and 9. After the tape is up to speed and K4 releases, the break at K4 contacts 6 and 10 inserts resistors R61, R62, and R63 in the armature paths to establish proper winding and hold-back torque, since the acceleration period is now replaced by constant-velocity operation.

From Play To Stop

Directly beneath the take-up reel hub on the take-up motor shaft is mounted a ball bearing. The outer race of this bearing is not rigidly mounted but is centered in a light-weight vane. The vane would rotate with the take-up motor shaft but is prevented from doing so by two posts. The vane rests against one post when the motor turns in one direction and shifts through an angle of about 15 degrees to rest against the other post when the motor turns in the other direction. The vane carries a small magnet, which causes operation of reed switch S14 when the motor runs in the forward direction. Switch S14 is released and S13 is caused to close when the motor turns in the reverse direction.

With the machine in the play mode, if the STOP pushbutton is pressed the following takes place: Bus voltage is applied from K3 contacts 10 and 2 through J6-11, J2-12, J2-11, and the closed contacts of S3, through J6-8, to operate relay K8. Bus power from J6-D is applied through S14, which is closed in the forward direction, through J5-18, K8 contacts 6 and 10 to operate K7. Relay K7 closes a holding path for relay K8 through K7 contacts 12 and 8, K8 contacts 8 and 12, to K8 terminal 14, so that K7 and K8 both remain operated after pressure is removed from S3. The REWIND lamp is lit through K7 contacts 11 and 7. The break at K8 contacts 3 and 11 opens the holding circuit for K5, extinguishing the PLAY lamp and dropping out the capstan idler solenoids so as to release the tape from the capstan.

Relay K5, however, does not release immediately when its holding circuit is broken due to the charge on C13 and C14. This delay is necessary in order to allow sufficient time for the capstan idlers to release their tension on the tape before the braking action is initiated to stop the capstan motor.

When K5 releases, ac power is removed from the capstan motor due to the breaking of K5 contacts 7

and 11. Concurrently with the removal of the ac power, dc power is applied to the capstan motor, which causes a dynamic breaking action on the motor, bringing it to a rapid stop.

The dc braking power applied to the capstan motor when the STOP button is pressed with the transport operating in the play or record mode (K5 energized) is provided by the capstan start-stop assembly 56013A170. The operation of this circuit assembly follows.

As described earlier, the capstan is started when K5 operates to close contacts 7 and 11, which applies ac power to the capstan motor. AC power is also applied at this time to J12-4 on the capstan start-stop control assembly. P12-4 routes the ac line power to the junction of R102 and R103. R103 is in parallel with R102 through closed contacts 10 and 2 of K101. Diode CR102 is connected in such a manner to R102 and R103 that it will conduct during the negative swing of the ac power cycle, charging C102. The return path for C102 is through K101 contacts 3 and 11. When power is applied to J12-4, C102 charges very rapidly through the low resistance of R102 and R103 in parallel, causing relay K101, which is connected across C102, to operate immediately. When K101 operates, contacts 10 and 2 are broken, removing R103 from the charging path. This increases the resistance 10 fold, limiting the voltage rise across the coil of K101 to the nominal operating value for the relay.

When K101 operates, capacitor C101 is charged through R101, CR101, closed contacts 8 and 12 of K101, and J12-1 which is connected to one side of the ac power line. When K5 releases, contacts 11 and 7 are broken, removing ac power from the capstan motor and J12-4 on the capstan start-stop control board. K101 releases approximately 0.5 second after the removal of ac power from J12-4. This delay is due to the charge on C102 across the coil of K101. During this time, brake power is supplied through J12-1, contacts 8 and 12 of K101, CR101, R101, J12-2, contacts 3 and 11 of K5 to the capstan motor. This rectified dc power applied to the motor causes its rotating inertia to be overcome very rapidly, bringing the capstan to a stop. When K101 releases after the delay period, contacts 8 and 12 open, removing power from the braking circuit. Capacitor C103 provides arc suppression between K101 contacts 8 and 12. Capacitor C101 continues to discharge through the capstan motor until its charge is dissipated.

Capacitor C102 is connected in the charging circuit in such a manner that, if relay K101 should be removed from its socket, one side of the capacitor is opened through contacts 11 and 3 or 11 and 7. If C102 remained in the circuit and the relay was removed with the transport operating in the play or record mode, the voltage developed across C102 would exceed the dc breakdown voltage of the capacitor. Because of this, relay contacts 3, 7, and 11 on K101 are used to remove C102 from the circuit to prevent damage to the capacitor in the event K101 is removed.

When the STOP button S3 is pressed, relays K8 and K7 operate; the operation of K7 provides full torque power through K7 contacts 5 and 9 and through J6-A to the rewind motor, while the break at K7 contacts 2 and 10 removes all take-up motor torque. The tape comes to a standstill and attempts to start in the reverse direction. Motion of the tape in the opposite direction, however, causes the vane in the sense switch assembly to leave its former position against the forward stop and swing toward the reverse stop. When the magnet moves away from S14, this switch opens, dropping out K7. This applies a light holding torque to the tape. When K7 releases, it releases K8 by opening K7 contacts 8 and 12. Relay K4 is held closed through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3, K5 contacts 12 and 4, CR13 and R5. It previously operated through K7 contacts 12 and 8, CR14 and R5. With the exception of K4, all relays are deenergized and STOP lamp DS3 is lit.

From Stop To Rewind

With the machine in standby, pressing REWIND pushbutton S2 causes bus voltage to be applied tbrough K3 contacts 10 and 2, J6-11, J2-12, J2-11, S3, S2, J5-R, and K8 contacts 2 and 10, which operate K7. This relay applies rewind torque through K7 contacts 5 and 9, as outlined above; and K7 locks up to the power bus through K7 contacts 11 and 7, and K8 contacts 2 and 10. The tape accelerates in the rewind direction with full power on the armature of the rewind motor. Since this is a dc shunt motor, it would reach a certain terminal velocity at which time tape would be loosely wound except for the following feature. As the tape comes

up to speed in rewind, the armature of the take-up motor is open circuited because of the break at K7 contacts 2 and 10. It operates as a dc generator without load until a definite terminal voltage is reached, the voltage rising as the speed increases. Zener diodes CR52 and CR53 will not pass current until the total potential across the diodes reaches 60 volts. Therefore, when the generated voltage reaches this level, current flows through J9-4, J6-S, CR53, CR52, J6-2 and J9-3 to act as a load and effective brake on the take-up motor, limiting the maximum speed at which it will supply tape and thereby providing a controlled tension in the reel being filled. Closure of K7 contacts 12 and 8 provides a path through CR24, and J6-14 to open the head shield door and through J6-15 to operate the tape lifters.

When either K5, K6, or K7 release, removing power from the armature of the take-up or rewind motor, an arc would normally develop between the breaking relay contacts due to the large inductive load of these motors. Two circuits are incorporated to reduce or suppress this arcing in order to increase the life of these relay contacts. CR30, R10, C5, and C6 constitute one of these arc suppression circuits. CR30 and R10 provide a common charging path for C5 and C6 which are connected to K7, 9 and 10, respectively. The opposite junction of CR30 and R10 is connected to the positive bus of the bridge rectifier power supply. Consider the transport to be running in the rewind mode, power being supplied to the armature of the rewind motor through closed contacts 5 and 9 on K7. Capacitor C5 is discharged at this time due to the closed contacts 5 and 9 on K7. When the transport mode of operation is changed, K7 will release, breaking contacts 5 and 9. Instantly, capacitor C5 will charge very rapidly to the power supply potential through CR30, thus absorbing, to a large measure, the current that would normally cause arcing as contacts 5 and 9 are drawn apart. C6, in the same manner, shunts the current away from contacts 6 and 10 on K5, and K6 when these relays release. The discharge path for C5 and C6 is provided through R10 and the closed contacts of their associated relays when they are energized.

To provide still further protection against relay contact damage, a second circuit is also used to suppress arcing between the relay contacts mentioned above. Two high voltage power transistors Q1, and Q2 are used to effectively shunt the relay contacts whenever these relays are released, removing power from either the rewind or take-up motor. The collectors of Q1 and Q2 are at the positive bus potential supplied from the junction of CR47 and CR49 through P5-11 and J9-1. The motor armature circuit supplying power to the rewind motor is connected to the emitter of Q1 through connector J7-3. This arrangement places Q1 in parallel with contacts 5 and 9 on K7. During the period in which K7 is energized providing power through contacts 5 and 9 to the rewind motor, capacitor C1 will charge to the power supply bus potential. The charging path for C1 is provided from the junction of CR46 and CR48, through P5-L, R60 or S7 if in the WIDE position, J9-4 to C1, through R1, CR1, J7-3, J6-A, closed contacts 5 and 9 on K7, jumper E11/E15 to the positive return of the bridge rectifier at the junction of CR47 and CR49. When K7 releases, contacts 5 and 7 are broken, which removes the short circuit between the collector and emitter of Q1, the charging path for C1, and power to the rewind motor. Instantaneously, the charge on C1 causes Q1 to conduct, shunting the current that would be drawn in the form of an arc between the opening contacts of the relay. The current through Q1 to the rewind motor after K7 releases will decay exponentially due to the discharging of C1 through R1, R2, J7-3, and the armature of M2.

The operation of Q2 is identical to the operation of Q1, providing arc suppression between contacts 6 and 10 on K5 and K6.

From Rewind To Stop (Tape Moving in Rewind Direction)

Pressing STOP switch S3 operates relay K8 through K3 contacts 10 and 2, J6-11, J2-12, J2-11, S3, and J6-8. Since tape is moving in the rewind direction, the sense switch vane has caused S13 to be closed. Therefore, K6 is caused to operate through J6-D, J9-6, S13, and K8 contacts 5 and 9. Relay K8 is locked up through K6 contacts 11 and 7, K8 contacts 8 and 12, and K6 is held up by S13. Relay K7, however, is released by the break at K8 contacts 10 and 2 and the fact that S14 is open. The power that was supplied to the rewind motor through K7 contacts 5 and 9 is removed by its release and transferred through operation of K6 through K6 contacts 6 and 10 to the take-up motor, which now operates to bring the tape to standstill and attempts to reverse it to the forward direction.

As soon as the sense switch vane moves away from S13 toward S14, S13 opens, releasing K6 and placing all circuits in the standby condition. During the stopping interval, the REWIND lamp goes out and the FORWARD lamp is lit from release of K7 and operation of K6. In standby, the tape lifter solenoid is released and K8 is released by the break at K6 contact 7 and 11. The head cover door remains operated through S-12, J6-M and CR-26, unless manually overridden to break S-12. Relay K4 remains energized throughout the above action, either through K7 contacts 12 and 8, CR14; or through K6 contacts 11 and 7, CR14; or through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3 and K5 contacts 12 and 4 and CR13.

From Rewind To Stop (Tape Moving in Forward Direction)

It is possible while shuttling the tape at high speed to have the tape moving in the forward direction but to have the controls in the rewind mode. If the STOP pushbutton is pressed at this time, K8 is energized in the manner described above; however, K7 is not released in favor of K6 because the sense switch vane is in position to cause S14 to be closed and S13 open. Thus, K7 remains energized and the tape comes to standstill and attempts to reverse, at which time the sense switch opens S14, releasing K7 and putting the machine in standby. At this time the tape lifters are released and K8 is released by the break at K7 contacts 8 and 12. The door solenoid remains energized through S12, unless overridden manually to break S12.

From Stop To Forward

With the machine in standby, pressing the FORWARD pushbutton causes bus voltage to be applied through K3 contacts 10 and 2, J6-11, J2-12, J2-11, S3, S2, S4, J5-S, CR17 and K8 contacts 1 and 9 to operate K6. Relay K6 applies full torque to the take-up motor through K6 contacts 6 and 10, K7 contacts 2 and 10, J6-2, and J9-3, causing tape to accelerate in the forward direction. Relay K6 locks up to the power bus through K8 contacts 9 and 1, K6 contacts 8 and 12, and K7 contacts 3 and 11. Motor speed is limited by the action of Zener diodes CR52 and CR53 as described before.

Closure of K6 contacts 11 and 7 provides a path through CR24 to open the head shield door and through J6-15 to operate the tape lifters.

From Forward To Stop (Tape Moving in Forward Direction)

Pressing STOP switch S3 operates relay K8 through K3 contacts 10 and 2, J6-11, J2-12, J2-11, S3 and J6-8. Since tape is moving in the forward direction, the sense switch has caused S14 to be closed and S13 to be open. Thus, K7 is operated through J6-D, S14, J5-18, and K8 contacts 6 and 10. Relay K8 is locked up through K7 contacts 12 and 8, and K8 contacts 8 and 12. Relay K6, however, is released by the break at K8 contacts 9 and 1. The power that was supplied to the take-up motor is cut off by the break occurring at K6 contacts 6 and 10 and applied through closure of K7 contacts 5 and 9 to the rewind motor, which now operates to bring the tape to standstill and attempting to reverse it to the rewind direction. As soon as the sense switch vane moves by reversal of tape motion, it releases S14, thereby releasing K7 and placing all circuits in standby. During the stopping interval, the FORWARD lamp goes out and the REWIND lamp lights because of the release of K6 and operation of K7. In standby, the tape lifter solenoid is released. K8 is released by K7 contact 8 and 12. The door solenoid remains energized through S12 unless manually overridden to break S12.

From Forward To Stop (Tape Moving in Rewind Direction)

It is possible, while shuttling tape at high speed, to have the tape moving in the rewind direction but to have the controls in the forward mode. If the STOP button is pressed at this time, K8 pulls in the manner described above. However, K6 is not released in favor of K7 because S13 is held closed by the sense switch vane while S14 is open. Thus, K6 remains operated and the tape comes to standstill and attempts to reverse, at which time the sense switch opens S13, releasing K4 and putting the mechanism in standby. At this time, the lifter solenoid is released, and K8 is released by the break at K6 contact 7 and 11. The door solenoid remains operated through S12 unless manually overridden to break S12.

From Forward To Rewind

Considering the tape to be in the forward mode regardless of its actual direction, relay K6 is energized. Pressing the REWIND pushbutton closes a circuit to operate K7 through K3 contacts 10 and 2, J6-11, S3, S2, J5-R, K8 contacts 2 and 10 to K7-14 through K7-13, CR19 and R6 to ground. Relay K7 operates, opening the holding path for K6 at K7 contacts 3 and 11, which releases, further breaking its holding circuit at K6 contacts 8 and 12. Torque power to the reel motors is, therefore, reversed. Relay K7 locks up through K8 contacts 10 and 2, and K7 contacts 7 and 11.

From Rewind To Forward

Considering the tape to be in the rewind mode regardless of its actual direction, relay K7 is energized. Pressing the FORWARD pushbutton closes a circuit to operate K6 through K3 contacts 10 and 2, J6-11, J2-12, J2-11, S3, S2, S4, J5-S, CR17, and K8 contacts 1 and 9 to K6-14. Because J5-S applies bus potential to CR20 as well as to CR17, the coil of K7 is effectively shorted, since the total voltage appears across R6. This releases K7, K6 remains operated over the path K7 contacts 11 and 3, K6 contacts 12 and 8, and K8 contacts 1 and 9. Torque to the reel motors is, therefore, reversed.

From Rewind To Play

In the rewind mode, regardless of actual direction of tape motion, relays K7 and K4 are energized. Pressing PLAY pushbutton S5 causes bus power to flow through S5, J6-18, and CR4 to operate K3. A holding path is established through K7 contacts 12 and 8, K3 contacts 11 and 7, R1, CR8 and CR7 so that K3 will not release when S5 is released. Relay K3 contacts 10 and 2 open the paths to S3, S2 and S4 pushbuttons to render them inactive at this time. The potential from K7 contacts 12 and 8 through K3 contacts 11 and 7, and through R1 also feeds through CR9 to terminal 14 of K8, causing it to operate. Whether K7 continues to hold or to transfer to K6 is determined by the direction the tape is moving, as outlined above. In any event, operation of K8 functions to bring the tape to standby condition. When K6 or K7 is released by the sense switch as the tape reaches standstill and attempts to reverse, the break at K6 contacts 7 and 11 or K7 contacts 8 and 12 releases K8. Normally, the machine would now remain in standby, but at this time K3 is still operated even though its supply path through K3 contacts 7 and 11 is open. This is because it is held by the charge in C1 for sufficient time to perform an additional function. When K8 releases, bus power is supplied through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3, K101 contacts 1 and 9 and K3 contacts 8 and 12 to operate K5. The functions from here on are as described in the paragraph, "From Standstill to Play."

From Forward To Play

In the fast-forward mode, regardless of actual direction of tape motion, relays K6 and K4 are energized. Pressing PLAY pushbutton S5 causes bus power to flow through J6-D, J2-9, J2-10, S5, J6-18, and CR4 to operate K3. A holding path is established for K3 through K6 contacts 11 and 7, K3 contacts 11 and 7, R1, CR8, and CR7 so that K3 will not release when S5 is released. Relay K3 opens the paths to S3, S2, and S4 pushbuttons to render them inactive at this time. The potential from K7 contacts 12 and 8 through K3 contacts 11 and 7 and R1 also feeds through CR9 to terminal 14 of K8, causing it to operate. Whether K6 continues to hold or to transfer to K7 is determined by the direction of tape movement. In any event, operation of K8 functions to bring the machine to a standby condition. When K6 or K7 is released by the sense switch as the tape reaches standstill and attempts to reverse direction, the break at K6 contacts 7 and 11, or K7 contacts 8 and 12, releases K8. Normally, the machine would now remain in standby, but at this time K3 is still energized, even though its supply path through K3 contacts 7 and 11 is open. This is because it is held by the charge in C1 for sufficient time to perform an additional function. When K8 releases, bus power is supplied through K7 contacts 11 and 3, K6 contacts 12 and 4, K8 contacts 11 and 3, and K3 contacts 8 and 12 to energize K5. The functions from here on are as described in paragraph, "From Standstill to Play."

Tape Runout

When the tape runs out from any mode of operation, the light from lamp DS8 falls upon photo diode V60, causing K1 to energize. This action opens the bus supply to all other relays. All power is, therefore, removed from the armatures of the

take-up and rewind motors. A short circuit is applied to the armature of each motor. One such circuit is through J9-4, J6-S, K1 contacts 10 and 6, J6-4, J2-1, J2-2, J5-P, K5 contacts 2 and 10, K6 contacts 2 and 10, K7 contacts 2 and 10, J6-2 and J9-3. The other circuit is through J7-4, J6-S, K1 contacts 10 and 6, J6-4, J2-1, J2-3, J5-V, K5 contacts 1 and 9, K6 contacts 1 and 9, K7 contacts 1 and 9, J6-A, and J7-3. As the fields are fully excited, this system acts to brake the motors to a standstill, since they operate as dc generators operating into a short circuit.

Record Mode Operation

To select the record mode the RECORD and PLAY buttons must be pressed simultaneously. This action reduces the possibility of accidental activation of the record mode while satisfying the switch logic requirements to activate the record circuits. Simultaneously pressing the RECORD and PLAY buttons will apply bus power to J6-18 through S5, and to J5-13 through S5 and S1. If the recorder was previously in the standby mode (STOP light illuminated), K3 will operate, placing the recorder in the play mode as described earlier. Positive bus power is applied to the collector of Q4 via J5-13, S1, and S5. The base of Q4 is connected through R24 to the holding circuit of K5, which is at the positive bus potential. With the collector and base connected to the positive bus in this manner, Q4 will conduct through the coil of K2, causing the relay to operate. A holding circuit is established through contacts 8 and 12 of K2 through CR55 to the collector of Q4 allowing Q4 to continue to conduct and holding K2 in when the RECORD button is released. The path established to hold K2 then lights DS1 through J6-3 and supplies positive bus voltage to the electronics power cable through connector J4-9, which is routed to the MASTER RECORD relay in the signal electronics assembly. Relay contacts 11 and 7 provide the ground return for the MASTER RECORD relay through J6-T. The positive bus potential at the collector of Q4 is also applied through R16 and CR29 to the bias oscillator. Capacitor C7 provides decoupling from the bus power supply and also causes the voltage applied to the oscillator to decay exponentially when power is removed. Transistors Q2 and Q3 operate as a low power push-pull oscillator to provide a high frequency signal to J6-U and J6-V. The bias signal is routed to the bias/erase amplifier boards in the signal electronics assembly through connector pins J4-1 and J4-2 and its associated cable.

Speed Change Switch

Speed change switch S8 selects windings of the capstan motor to provide either of two speeds. These are related by the ratio 2:1 and, therefore, can be provided for tape speeds of 7½ and 15 ips, or 15 and 30 ips, etc. Dc bus potential is supplied to either J4-6 or J4-7 in the electronics power cable, depending on the motor speed, in order to control the equalizer-select relays on the circuit boards in the signal electronics assembly.

Monitor Switching

Two pushbuttons on the transport, S10 and S11, are arranged to transfer the output line amplifier and VU meter of each channel from the incoming signal source to the playback signal and vice versa. Pressing A switch S10 applies positive bus voltage from J6-D through J2-9, J2-10, and S10 to J4-5, which is in the electronics power connector, causing operation of the A/B transfer relays in each channel. Similarly, B switch S11 applies a ground to terminal J4-4 to cause reverse operation of the transfer relays. These switches are momentary contact types and are not backlighted.

Tape Width Switch

It is necessary to provide two torque ranges for the reel drive motors due to the difference in weight and tape handling characteristics between 1 and 2 inch tape. Compensation in the torque requirements between tape sizes is provided by S7 and R60. The amount of torque developed by the reel drive motors M2 and M3 is dependent, to a large extent, on the amount of current that can be drawn from the bridge rectifier power supply CR46 through CR49. To provide the proper torque to the drive motors when 1 inch tape is used, the current path from the power supply is from the junction of CR46 and CR48 through P5-L and R60 to J9-4 and J7-4, which completes the path to the armature of M2 and M3 from the negative side of the power supply. A path from the junction of CR46 and CR48 through R60 is also provided to the fields of M2 and M3. With a common current path to both motors established through R60, its resistance value will control the amount of torque developed by the

motors. The resistance value of R60 is such that the amount of torque delivered to the drive motors when 1 inch tape is used is sufficient to properly perform the take-up and rewind handling of the tape. When 2 inch tape is to be used on the transport, R60 is shorted through S7, removing it from the current path and allowing the drive motors to draw an additional amount of current from the power supply. This provides the necessary increase in torque required to drive the larger 2 inch tape reels and provide a greater tape wrap tension for proper transfer from one reel to the other.

SIGNAL ELECTRONICS FUNCTIONS

Processing of the output signal to be recorded and the signal extracted from the recorded tape (play-back) is accomplished in the signal electronics assembly. Four plug-in circuit boards provide the necessary signal processing for each record/playback channel. In addition to the circuit boards, the signal electronics assembly contains the necessary signal switching circuits which control the various modes of operation of each channel.

The plug-in circuit boards associated with each channel are described in detail after the following description of their use in the overall operation of the recorder.

Record Mode (See figure 22.)

The signal to be recorded is applied through connector J-A to the primary of transformer T-A, which reflects an impedance of 20,000 ohms to the signal source. The secondary of T-A is connected across the RECORD LEVEL control R-A, which establishes the signal level applied to the record amplifier. This amplifier provides preemphasis, equalization, and linearization to the signal, and sufficient gain to drive the record head. A relay on the board selects the proper equalization for two tape speeds. This relay is controlled by the tape SPEED switch on the transport. Linearization is selectable by means of a switch on the circuit board and is adjustable. The degree of linearization required depends on the signal level, and corrects for distortion that occurs as the signal level approaches the saturation level of the tape.

In addition to the record amplifier, a monitor amplifier on the board provides sufficient signal amplification of the input signal to drive the line amplifier. The line amplifier output is applied to the VU meter and output connector J-F for monitoring of the input signal. A RECORD MON. CAL. control on the record amplifier board enables the monitor amplifier gain to be adjusted so that, without the linearizer circuit in service, 3% total harmonic distortion on playback produces a reading of 6 dB above zero VU on the VU monitor meter.

The record signal from the record amplifier board is connected to contact 12 on the record relay K-B. This circuit is normally grounded until relay K-B is operated through the mode select switches on the remote control box and the RECORD function switch on the transport panel. When K-B operates, the signal is applied through contacts 12 and 8 to the bias/erase amplifier board at terminal 22 on connector J-B. Operation of the record relay K-B also applies 28 volts dc power to the bias/erase amplifier at terminal 12 on connector J-B. A 120 kHz bias oscillator is energized in the transport when the record mode is selected. This bias signal is applied to the bias/erase amplifiers in each channel at terminals 14 and 15 on board connector J-B. This signal is amplified by the bias amplifier to the proper magnitude to drive the record head. The audio signal at terminal 22 is coupled to the bias output through a bias trap circuit which has no effect on the audio signal but offers a high impedance to the 120 kHz bias signal, thus preventing the bias from being fed back into the record amplifier. A bias amplitude control provides adjustment of the bias output level to the record head, and a noise balance control allows an adjustable amount of dc signal component to be applied to the record head to correct for any external fixed magnetic fields in the vicinity of the record head gap.

Bias current through the record head can be monitored at the TP BIAS test point, which is connected to the record head return with a 27 ohm resistor to ground.

The record signal and bias is applied to the record head through contacts 3 and 9 on the normal-sync relay K-C which is deenergized, as shown, when the selected channel is operated in the record mode.

A second power amplifier, also driven by the 120 kHz signal, applies its output through terminal 21 on the bias/erase amplifier board to variable

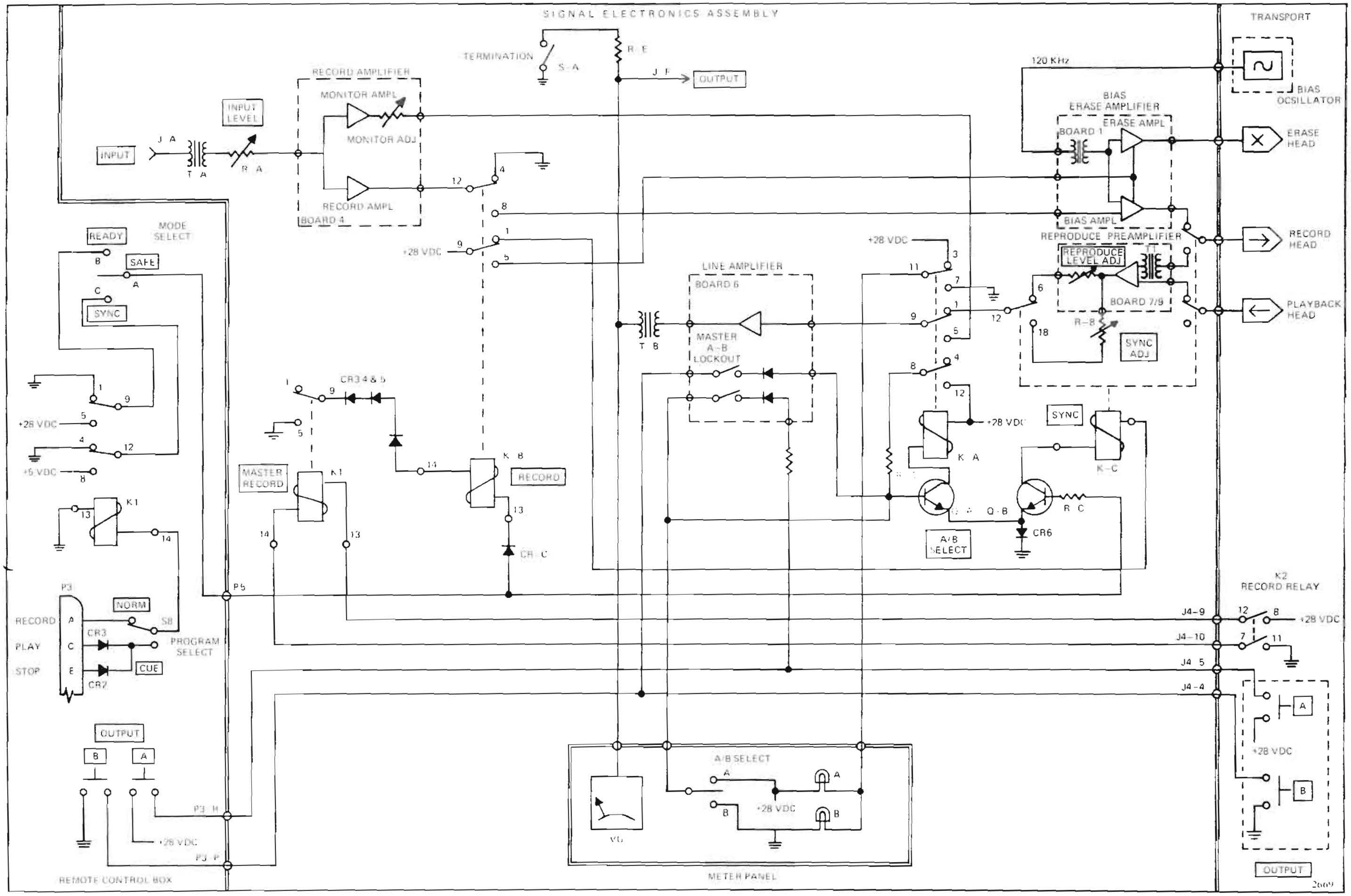

Figure 22. Signal Electronics, Simplified Block Diagram

capacitor C-A, which couples the signal to the erase head. Capacitor C-A adjusts the amount of erase current supplied to the erase head. The erase head current can be monitored at TP-A, which is connected through terminal 16 to a 10 ohm resistor in the return path from the erase head. Inductor L-A and capacitor C-B provides the proper reactance to tune the secondary of the erase amplifier output transformer and erase head to the 120 kHz signal.

Playback Function (See figure 22.)

Signals recorded by the circuits described in preceding paragraphs will be reproduced by the corresponding playback head and may be monitored on the VU meter or at the OUTPUT jack when the B OUTPUT select button is pressed. The playback output signal will be delayed from the corresponding record signal by an amount equal to the linear distance between the record head and the playback head times the tape speed. This delay is slight, however, and represents no difficulty when monitoring the input/playback quality of the recording.

The signal induced in the playback head is connected to terminal 4 on the reproduce amplifier board connector J-C through contacts 1 and 7 on the normal-sync relay K-C. The preamplifier board provides the required signal gain to drive the line amplifier, high and low frequency equalization, and phase correction for two tape speeds.

In the normal playback mode, the reproduce preamplifier output is taken from terminal 22 on board connector J-C. The signal level at this output terminal is controlled by R17, the REPRODUCE LEVEL potentiometer on the preamplifier board. This control is normally adjusted to produce an output of zero VU with a standard reference level tape providing a 700 Hz signal tone at the reproduce head.

The reproduce signal at the junction of R-F and R-H is routed through contacts 6 and 12 on the normal-sync relay K-C to the A/B select relay contact 1. When the B output is selected, the reproduce signal will be applied to the line amplifier input through contacts 1 and 9 on the A/B select relay, as shown. The reproduce signal output from the line amplifier will then be displayed on the VU meter and routed to the output connector J-F.

Sync Playback Function (See figure 22.)

When the sync mode of operation is selected the normal-sync relay K-C operates, disconnecting the playback head from the reproduce preamplifier input, and connects the record head through T1 to the reproduce preamplifier. Due to the operation of the normal-sync relay, the normal playback head has been completely disconnected and the record head connected to the primary of T1, which couples the sync input to the reproduce amplifier. The use of transformer T1 provides an improved impedance match between the record head (used as a playback head) and the reproduce amplifier input. When the record head is used as a playback head, it matches closely the frequency response and gain of the normal playback head. Due to its wider gap, however, the extreme high frequencies suffer some attenuation, depending upon the tape speed.

Mode Select Circuits (See figures 22 and 25.)

The operational mode of each channel in the signal electronics assembly is selected at the remote control box. Each channel is provided with a mode select switch, allowing three (3) modes of operation to be chosen, i.e., READY, SAFE, and SYNC. The RECORD and SYNC relays associated with each channel in the signal electronics assembly provide the required mode switching within the electronic circuits of the selected channel. These relays respond to the mode selected at the remote control box when the transport tape motion controls are activated. In conjunction with the mode select switches, an additional switch is provided on the remote control box panel, which is referred to as the program select switch. This switch, depending on its position, i.e., NORM or CUE, determines the transport mode of operation that will activate the electronic circuits of the channel or channels preprogrammed by the mode select switches. This feature is especially useful when overdub recordings are made, as will become apparent during the following discussion of the mode selection circuits.

Activation of the mode select circuits are initiated by +28 volts dc commands originating from the tape transport control circuits. These commands are routed to the remote control box via connector P3, pins A, C, and E. Operation of relay K1 depends on the position of the program select switch S8 and the transport mode of operation selected. When S8 is in

the NORM position, operation of K1 will only occur when the transport record mode is selected. Under these conditions, +28 volts dc is provided to terminal 14 on relay K1 through the closed contacts on S8, which is connected to P3-A. The +28 volts dc provided at P3-A when the record mode is activated is also applied to DS1, which illuminates the RECORD selector switch S1 on the remote control box. With S8 in the CUE position, operation of K1 will occur when the transport is operated in the record, play, or stop mode. +28 volts dc from the transport is provided to P3-C when either the record or play mode is selected. From P3-C, this potential is applied through CR3 and the contacts of S8 to terminal 14 on relay K1, causing it to operate. DS5 is also connected to P3-C, causing the PLAY selector switch S5 to illuminate when the play or record mode is active. When the transport is in the standby mode (STOP selector switch S3 illuminated), +28 volts dc is provided to P-3E, which also causes K1 to operate through CR2, S8 to terminal 14. CR2 and CR3 are connected back-to-back, thus preventing illumination of the PLAY indicator lamp when the transport is in the STOP mode and the STOP indicator lamp from illuminating when the transport is operated in the PLAY or RECORD mode.

Operation of relay K1 provides two descrete voltages to each mode select switch. +28 volts dc is supplied to the upper contact on each mode select switch from P5-U through closed contacts 5 and 9 on K1. The +28 volt potential on K1-9 is also applied through R1 to zener diode VR1 and produces a regulated voltage of approximately +5 volts dc at K1-8, which is tied to the junction of R1 and VR1. C1 provides a delayed build up of the +5 volts dc across VR1 when K1 operates. The +5 volts dc is applied to the lower contact on each mode select switch through closed contacts 8 and 12 on K1. The middle contact of each mode select switch can be positioned so as to provide either +28 volts dc (READY mode) or +5 volts dc (SYNC mode) and, when left in the center position (SAFE mode), an open circuit (zero volts) to the record and sync relay circuits of the respective channel in the signal electronics assembly.

The record and sync relay circuits are identical in each signal channel, each being programmed by the mode select switches at the remote control box. The control voltage at on the middle contact of each mode select switch is routed through P5 to its respective signal channel. This control voltage is applied to terminal 13 of the RECORD relay (K-B), through diode (CR-C), and to the base of the SYNC relay drive transistor (Q-B) through resistor (R-C). As mentioned earlier, activation of the mode select circuits are initiated by the transport logic control circuits which operate K1 in the remote control box. Two distinct sequences of operation are provided by the program select switch. Let us first consider S8 in the NORM position. K1 in the remote control box will operate, applying +5 volts dc and +28 volts dc to contacts B and C, respectively, on each mode select switch only when the transport is activated in the RECORD mode. Assume that the READY and SYNC mode has been selected for several channels. On those channels selected for the READY mode, +28 volts dc will be applied from the upper contact of the mode select switch through the remote control cable and connector P5 to the junction of CR-C and R-C in the signal electronics assembly. Simultaneously with the application of the +28 volts dc control voltage, the MASTER RECORD relay (K1) will operate due to the closing of record relay (K2) on the transport logic board. This relay places +28 volts dc on terminal 13 and ground to terminal 14 on the MASTER RECORD relay, causing it to operate. Operation of the MASTER RECORD relay provides a ground return for the coil on each RECORD relay (K-B). This path is from terminal 14 on each relay (K-B) through CR3, CR4, CR5, and closed contacts 9 and 5 on MASTER RECORD relay (K1). Those channels that have been programmed to operate in the record mode (mode select switch in the READY position) will cause the RECORD relay in the channel selected to operate due to the presence of +28 volts dc, which is applied through CR-C to terminal 13 of the RECORD relay. The +28 volts dc control voltage is also applied to the base of the SYNC relay drive transistor through R-C. This would normally cause the transistor to conduct, causing the SYNC relay to operate, if it were not that to the breaking of contacts 9 and 1 on the RECORD relay removing +28 volts dc from the SYNC relay coil which has its return connected to the collector of the SYNC relay drive transistor. The slow rise of voltage across VR1 in the control box prevents any momentary operation of the SYNC relays prior to operation of the individual RECORD relays. Thus the +28 volts dc command from the mode select switches at the remote control box has caused the RECORD relays of the selected channel(s) to operate when the transport is activated in the record mode.

Those channels selected to function in the sync mode are supplied with +5 volts dc from the mode select switches. This potential, applied through CR-C to the RECORD relay (K-B), is not sufficient to cause the relay to operate. However, it is of sufficient level to forward bias the SYNC drive transistor on, causing the SYNC relay to operate. The +28 volts dc in this case is maintained through contacts 9 and 1 of the RECORD relay (K-B) to the coil of the SYNC relay and, in return, to the collector of the SYNC drive transistor.

Channels in which the mode select switches are placed in the SAFE position will present an open circuit or no command voltage to the RECORD and SYNC relays in the signal electronics assembly. Under this condition, the RECORD relay(s) K-B are unable to operate, preventing accidental erasure of any prerecorded material. The SYNC relay is also prevented from operating due to the absence of bias voltage on the base of the SYNC drive transistors, thus allowing any recorded material on these tracks to be reproduced under normal playback conditions.

After a selection has been recorded with the program select switch in the NORM position, as in the preceding description, the same tape can be replayed in the normal reproduce mode without resetting of any switches on the remote control box. If a second recording attempt is necessary, starting the transport in the record mode will again activate the previously selected sync and record channels.

When it is necessary to listen to a prerecorded track for cuing purposes before the record mode is activated, the CUE position of the program select switch is used. This will allow relay K1 in the remote control box to operate when the transport is placed in the PLAY mode, as described earlier. The control voltages supplied to the mode select switches through the closed contacts of K1 will then cause those channels selected to operate in the SYNC mode.

Two 28 volt indicator lamps associated with each mode select switch indicate the mode selected for each channel. A red lamp indicates the READY mode selection, a green lamp indicates the SYNC mode selection, and the absence of illumination of either lamp indicates a SAFE mode selection.

DETAILED CIRCUIT DESCRIPTIONS OF ELECTRONICS

The following paragraphs contain detailed descriptions of each of the circuit boards used in the signal electronics assembly.

Nab Record Amplifier (Board 4) (See figure 28.)

The input signal to be recorded is applied at terminal 14, after it has passed through the input transformer and level control. C1 couples it to Q1, which is biased to the proper operating point by R1 and R2. After amplification, the signal is coupled by C3 to an equalizer network which provides pre-emphasis, boosting the high and low frequencies in accordance with standard NAB practice. This is accomplished as follows.

Consider R6 and R7 as an attenuator network, with R8 short circuited, as it effectively is at high frequencies because of C4 and C5. This attenuator network reduces the voltage swing at the junction of R6 and R7 from what it was at collector of Q1. However, if a bypass capacitor C18 or C19 is connected across R6 it permits the high frequencies to suffer less attenuation. The result is an adjustable rise in response for high frequencies. The degree to which this is true depends on the setting of the variable capacitor. Practical values of C18 and C19 make it necessary for the junction of R6 and R7 to appear always as a very high impedance. Current cannot be drawn from this point without upsetting the equalization characteristic. Thus, the junction is used to drive a field effect transistor, Q2. At the low frequency end of the spectrum C4 and C5 show increasing impedance as the signal frequency is lowered; therefore, the voltage at the junction of R6 and R7 would continue to rise as the frequency drops except that R8 provides a shelving off to prevent unnecessary sensitivity to subaudible frequencies.

Relay K1 automatically changes the high frequency equalization when tape speed is changed. The output of Q2 is applied to terminals into which may be inserted values of C8, C20, R11, and R12 to adjust for any requirement arising for shelving equalization, in addition to the normal NAB equalizers just described. All four components may be

eliminated in many instances, a jumper being furnished across the R11 or C20 terminals.

After this network, the signal is fed to the base of Q3 whose bias is set by R13, R14, and R15. This operates with Q4 in a Darlington circuit to provide gain and low impedance output at C11 to drive the record head. R18 normally provides a degree of degeneration, determined by the setting of R20 and R19 in series with C12 and C21. But the degree of degeneration can also be reduced by conduction of Q5 and Q6 when S1 is closed. Q5 and Q6 act to change the degeneration with instantaneous signal amplitude; thus, they tend to deform the signal whenever its amplitude attains a value sufficient to overcome their contact potential. This results in a distortion inverse to that which overload of the tape normally introduces. By employing Q5 and Q6 in this manner and properly adjusting the overall degeneration by means of R20, the LIN ADJ. control, it is possible to introduce the proper corrective distortion into the recording process so that the normal 3% tape distortion point, without such correction, shows somewhat less than 1% when this linearizer is employed.

C11 feeds the record head connected at terminal 22. R22 is a resistor in series with the head to establish a constant current characteristic. R23 provides a high resistance path to ground so that the ground side of C11 will always be discharged, even when no head is connected to terminal 22. This is a means of preventing accidental record head magnetization.

C14 couples the input signal to Q7. The gain of Q7 is adjusted by the combination of emitter resistors R27 and R28, which is bypassed by C16, to provide the proper range of signal levels to R30. This control, RECORD MON CAL., can be conveniently adjusted to serve the input signal audio monitoring and input signal VU meter monitoring circuits. R29 and C17 are provided to give a slight rise in output at 15 kc to make up for losses in the input transformer, wiring, and meter sensitivity occurring at the extreme end of the spectrum.

Bias And Erase Amplifier (Board 1) (See figure 29.)

Whenever the transport is put into the recording mode, a 120 kHz signal is generated within the transport and applied to all bias and erase amplifier boards at terminals 14 and 15. T1 operates as a bridging transformer. It has two secondaries. One of these feeds the base of Q2 through resistor R4. This resistor is employed to permit insertion of a feedback signal from R26. Q2 amplifies the 120 kHz signal and provides sufficient power to drive the push-pull amplifier Q5 and Q6. C13 and C14 tune the secondary of T4, and C16 and C17 tune the primary of T5 in order to minimize harmonic distortion. Even order harmonics are particularly objectionable, since they result in increased background noise recorded into the tape.

The output of Q5 and Q6 is fed through T5 and C18 to R19 and R24, the latter variable to control the amount of 120 kHz bias signal fed through terminal 1 to the record head. The audio signal comes from the record amplifier and is applied at terminal 22. It passes without loss through the tuned circuit L2, C19, and C21 which is tuned to present a high impedance to 120 kHz, thus preventing feedback of bias power to the record amplifier.

CR2 and CR3 each operate as half-wave rectifiers. If the arm of R23 is run to the end connected to CR2, then the upper end of R21 will have an average negative potential. Conversely, if the arm is run to the other end, then the upper end of R21 will have an average positive potential. R20 allows current set up by such potential to flow through R19 and R24 to the record head, thereby making it possible to inject a very small but adjustable dc current into the head, in addition to the audio and bias frequencies, to allow minimization of noise resulting from strong external magnetic fields or even order harmonic distortion from the bias supply.

These circuits are activated by application of potential at terminal 12. In order to prevent a recorded thump when the record button is depressed, R27 and C20 are provided to permit the dc bias on the base of Q1 to rise slowly, and C15 is provided across R17 for the same purpose on Q5 and Q6. The bias envelope, therefore, grows to operating level in a matter of about 10 milliseconds. When the recording mode is deactivated, another thump or click is avoided by allowing reservoir capacitor C2 to permit the bias waveform to decay to zero over a period of about 60 milliseconds. R1 allows C2 to charge at a reasonable rate when the circuits are activated without causing a surge on the power supply, but CR1 permits the capacitor to be connected directly to the load during discharge. L1 and C1 constitute a

filter to stop bias frequency ripple on the power bus connected to terminal 12.

The amount of drive applied to Q5 and Q6 is controlled by feedback resistor R26, which also improves the waveform at the output by cancelling out internally generated distortion products.

The second winding of T1 feeds the 120 kHz signal to an almost identical circuit, except that the output transistors Q3 and Q4 have a higher power rating in order to supply the erase head with sufficient drive to completely erase a saturated tape. The feedback signal input at terminal 19 is not connected in the Series 500 recorders, allowing a greater amount of drive current to be delivered to the erase head. Erase current is proportional to the voltage developed across R29 and is monitored by a test jack connected to terminal 16. Erase current test jacks for each channel are located on the signal electronics assembly front panel. The center tap secondary of T3, which is connected to terminal 20, is not used in the series 500 recorders. The record bias current can be monitored at TP1 because of the voltage developed across R22. R22 is in series with the ground return lead from the record head. R25, connected between terminals 2 and 3, is also inactive in this system.

Line Amplifier (Board 6) (See figure 30.)

This is a full-spectrum flat response amplifier which provides sufficient gain and output power to adequately drive an outgoing line at up to a peak level of +28 dBm (600 ohms).

Q1 is an emitter follower, accepting an input impedance of 10,000 ohms or lower and providing low impedance excitation for Q2. Q2 drives Q3 and Q4 (complementary symmetry types) to result in push-pull excitation of Q5 and Q6. A required static potential difference between the bases of Q3 and Q4 is established by the contact potential drop across CR1, CR2, and CR3.

CR4, R20, and C12; CR5, R19, and C11 are drift compensation networks that stabilize the operating points of Q5 and Q6. The dc operating point for these two transistors is set by R13, R14, and R15; and Q2, Q3, and Q4. A feedback path through C13, R21, and R22 assures minimum distortion for all signal frequencies. The output signal is coupled through C14, S1, and R24 to terminal 21. The signal at terminal 21 is routed to the primary of a 600 ohm line matching transformer. The output from the transformer is connected to the output jack for the respective channel and to the appropriate VU meter on the meter panel.

S2, CR6, and CR7 are used in the A-B monitor select circuits. When S2 is opened, the respective channel will not respond to the A-B transfer command when either the A or B pushbuttons on the transport or remote control box is pressed. The output transfer can only be accomplished with S2 open by pressing the respective A-B select switch on the meter panel. With S2 closed, A-B transfer will take place in the respective channel and all other channels in which S2 is closed whenever the A-B buttons on the transport are operated. CR6 and CR7 are isolating diodes, permitting all channels to operate from the A-B OUTPUT switches on the transport or remote control box but preventing the transfer switches on the meter panel from activating any channel(s) other than its own.

R1, R2, R3, R4, and R25 are not used in the Series 500 recorders.

Nab Preamplifier (Board 7/9) (See figure 27.)

This plug-in circuit board provides the required signal amplification of the playback head signal or the record head signal, when the later is used in the SYNC mode (overdub). In addition, the circuit board performs the necessary frequency equalization and phase correction for two tape speeds.

Two input circuits are provided on this board. When the selected channel is operated in the normal playback mode, the input signal is supplied from the playback head to terminal 4. When the selected channel is operated in the sync mode, terminal 4 is connected to terminal 16, the output of transformer T1. The primary of T1 is then connected to the record head through terminals 14 and 17. The input circuit is selected through the contacts of the normal-sync relay, external to circuit board. T1 provides additional signal gain and impedance matching to the preamplifier when the record head is used as a playback head. This is required due to the reduced voltage output of the record head when it is used as a playback head.

From terminal 4, the signal is applied to the base of Q1 through C1 and R2. The collector of Q1 is direct coupled to the base of Q2, providing a signal path and dc bias to the second amplifier stage. The output of Q2 is direct coupled to the base of Q3. A feedback path is also provided from the collector of Q2, through one of two RC frequency equalization networks, to the emitter of Q1. Relay K1 in the normal or deenergized condition (as shown for the primary speed tape operation) places C7, R18, R19, and R20 in the feedback path. When K1 is energized, C8, R21, R22, and R23 are placed in the feedback path, providing the proper frequency equalization for the secondary speed tape operation. C7 (or C8) with R20 (R23) controls the point where the customary 6 dB per octave correction becomes no longer effective at higher frequencies. R19 (or R22) controls the point at very low frequencies where the relation again no longer holds true, and the amplifier shelves off. The proper dc operating point for Q1 and Q2 is maintained by the bias established at the junction of R8 and R9 in the emitter circuit of Q2. This dc bias is applied through R5 to the base of Q1, thus providing a controlled amount of negative feedback to Q1 in relation to the input signal level. C4 filters out any ac component present at the junction of R8 and R9.

Q3 operates as a phase distortion correction stage. Considerable rotation of phase normally occurs in the overall process of recording and playing back tape, the situation being increasingly pronounced at shorter wavelengths. In copying tapes, the effect is compounded. Q3 and its associated circuits provide an effective correction for such distortion.

A paraphase signal output condition exists between the emitter and collector of Q3; that is, equal amplitude with 180 degree phase difference. C5, which couples the collector signal to the base of Q4, presents a high impedance to the low frequencies contained in the recorded signal. R13 (or R13 in series with R14, depending upon the state of K2) feeds the emitter signal directly to the base of Q4.

As a result of this action, the low frequency phase components present at the emitter of Q3 predominate at the base of Q4 and are 180 degrees out of phase with the same signal at the collector of Q3. Conversely, capacitor C5 presents a very low impedance to the higher signal frequencies, allowing them to pass readily to the base of Q4.

At intermediate frequencies, the vector sum of R13 (R13 and R14) causes the signal to be applied to the base of Q4 at some intermediate phase angle between zero and 180 degrees, while the amplitude remains constant throughout the entire frequency range.

The result of this frequency/phase shift action cancels the inherent phase distortion of the signal caused by the magnetic transfer characteristics when the signal was recorded on the tape.

In fast tape speed operation, K1 is deenergized as shown. During slow tape speed operation, K1 is energized which removes R14 from the circuit.

Emitter follower Q4 provides the required signal isolation and impedance output requirements. From the emitter of Q4, the signal is coupled through C6 to the reproduce level control R17. The output signal from the arm of R17 is connected to terminal 22; this signal is applied to the line driver amplifier through the contacts of the normal-sync relay and the A-B select relay when the selected channel is operated in the normal playback mode. The signal is also routed through R16 to terminal 21; this output is utilized to drive the line amplifier when the selected channel is operated in the SYNC mode.

Q5 is a series voltage regulator which provides regulated power from the input bus terminal 12 to the four transistor stages in this assembly. R24 and R25 establishes the proper operating point for Q5, thus establishing a fixed voltage drop across Q5. C10 provides filtering of any power supply ripple on the regulated voltage. C9 filters any ripple at the base of Q5.

M-56 FUNCTIONAL DESCRIPTION

USING THE 56017B100 REMOTE BOX

1. Push-button Controls

   a. Stop Button: Provides a stop command to the transport logic. May be engaged at any time to inhibit tape motion. The stop button is illuminated whenever the tape is stopped (only if the tape is threaded).

   b. Play Button: Provides a command to the transport logic to enter the play mode. If the machine has been in forward or rewind, the machine will automatically be given a stop command. The play button will illuminate when the play mode is actually entered.

   c. Record Button: Provides a record command to the transport logic when it and the "play" button are depressed simultaneously. The record button illuminates when the transport logic has issued the record command. Note: The machine will not accept a record command while still in a stopping mode.

   d. Forward Button: Provides a forward command to the logic. It may be engaged at any time. The forward button illuminates whenever the machine is in the forward mode.

   e. Rewind Button: Provides a rewind command to the transport logic. It may be engaged at any time. The rewind button illuminates whenever the machine is in the rewind mode.

   f. Output "A" Button: Provides a command to the signal electronics to present the in-coming lines of "buss" at the out-put jacks of the recorder. Illumination of the white indicator lamp above the corresponding meter indicates this mode.

   g. Output "B" Button: Provides a command to the signal electronics to present the recorded signals at the output jacks. Illumination of the amber indicator lamp above the corresponding meter indicates this mode.

2. Indicator Lamps

   a. Runout Indicator: Illuminates whenever the tape is not threaded in the "isoloop".

   b. Red-Record Indicators: Illuminate with varying intensity to incicate that the corresponding track is pre-set or "ready" to record, when the

master record command is issued. It illuminates with full intensity once the recording has started.

c. Green-Sync Indicators: Illuminate the full intensity to indicate that the record head is connected to the reproduce pre-amp for the over-dub function. Illumination with varying intensity indicates that the "sync" or over-dub mode will be entered with the record mode is entered.

3. Toggle Switches

a. Ready-Safe-Sync Switches:

(1) THE READY POSITION, programs the corresponding track to record and transfer its a/b relay to "A" (the incoming buss). If the normal-cue switch is in the cue position, the sync mode is engaged until the record mode is entered.

(2) THE SAFE POSITION, inhibits record and sync functions in all transport modes.

(3) THE SYNC POSITION, activates the sync relay to allow overdubbing if the normal-cue switch is in the cue position. If the normal-cue switch is in the normal position, the sync relay is inhibited until the record mode is entered.

b. Normal-Cue Switch: THE CUE POSITION, activates the cue relay which normally inhibits the sync command until the record mode is entered.

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M-56 SERIES 500

PREVENTATIVE MAINTENANCE AND ALIGNMENT PROCEDURE

A. Visual Inspection

1. Check for excessive or uneven wear of the components in the tape path.

2. Check for proper seating and connections of P.C. boards, relays, transistors, connectors and plugs.

3. Check cooling fans and air flow.

4. Check capstan speed in play mode.

5. Check all lamps and bulbs.

B. Cleaning and Degaussing

1. Clean all tape path surfaces.

2. Clean and degauss heads.

NOTE: Cleaning should be done using cotton swabs or lint free disposable wipers and isopropyl alcohol. Care should be taken to prevent excessive cleaning agents from getting into bearing or on the plastic surfaces of the end of tape lamp lens or photo cell.

C. Transport and Head Alignments

1. Correct tape speed in play mode, if necessary, by adjusting capstan belt tension (see Manual for details).

2. Adjust sensitivity of photo cell circuit for different types of leader tapes or to compensate for the aging of the photo cell.

3. Set capstan puck pressure (see Manual for details).

C. 4. Align reproduce and record head azimuth.

a. Run alignment tape at 700Hz. Set all levels for OVU.

b. Through the control console mix all 16 tracks to one output (decrease mixing amp level so total output level can be monitored on the console).

c. Adjust head azimuth for maximum output with the least amount of amplitude bounce at the higher frequencies on the alignment tape; fine adjustments made at 15KHz.

d. In sync mode repeat steps A through C above for the record head.

D. Playback Level and EQ Alignment

NOTE: The following is for 206/207 tape to obtain the best average signal-to-noise and headroom improvements.

1. Run alignment tape at 700Hz and adjust "Playback level Cal" for -2VU.

2. Repeat step 1 in sync mode and adjust "Sync Cal" for -2VU.

3. Adjust "High Frequency Playback Equalization" for -2VU at 10KHz.

4. Adjust "Low Frequency Playback Equalization" for -2VU at 50Kz.

E. Record Level and Equalization Alignments

1. Using a new or bulk degaussed tape place recorder in Run/Record mode.

2. Insert a 1KHz tone at +4dbm - set record level for OVU.

3. Set "Bias Level" for ½db overbias at 1KHz.

4. Reset record level if necessary.

5. Tune oscillator for 10KHz and set "Record High Frequency Equalization" for OVU.

6. Return to 1KHz at +4dbm - place meter circuit in "A" or Record mode and set "Record Mon Cal" to OVU.

F. Bias and Erase Circuit Alignment

1. Use AC-VTVM to monitor "Record Amp Test Point", place recorder in Run/Record made with no input signal. Tune the "Bias Trap" on the Bias and Erase card for minimum signal at the record amp test point.

2. Insert AV-VTVM into erase test point, tune erase coupling cap for maximum signal (approximately .55 volts AC).

3. Check degree of erasure. If necessay adjust R-3 on Bias and Erase card for additional erase current.

G. Noise Balance Adjustment

1. In Run/Record mode record 1000Hz at normal level (+4dbm).

2. Monitor output with a harmonic wave analyzer tuned to the second harmonic - 2000Hz.

3. Adjust noise balance for minimum second harmonic.

4. If wave analyzer is not available, in Run/Record made with no input signal - tune noise balance for minimum "grotzel" noise when monitoring through a power amp and speaker system.

H. Linearizer Adjustment

NOTE: As delivered, the recorder is adjusted for use with Scotch Brand low noise tape types 206/207 If the recorder is to use a different type of tape, the LINEARIZER ADJ control may require adjustment, as outlined below.

1. Place the LINEARIZER switch on No. 4 board to the off position.

2. Apply 1KHz at +10dbm to the INPUT. Connect a Wave Analyzer and VTVM to the reproduce OUTPUT.

3. Adjust the 1KHz oscillator input signal level for exactly 3 percent third harmonic distortion, as measured on the wave analyzer.

4. Place the LINEARIZER switch on the No. 4 board to the ON position. Adjust the LINEARIZER ADJ potentiometer to obtain minimum distortion on the wave analyzer. The third harmonic distortion

H. level should be less than 0.8 percent with the LINEARIZER switch ON and 3 percent with the LINEARIZER switch OFF. Leave the LINEARIZER switch ON after this adjustment is completed.

NOTE: The recorder may be operated with the linearizer distortion reduction circuit disabled if it is felt that this circuit is misaligned. This is accomplished by placing the LINEARIZER switch in the OFF position until proper alignment can be performed. Third harmonic distortion products will be more prevalent at the higher recording levels when operated under this condition.

I. Use of IM Distortion Analyzer

1. Using an IM Distortion Analyzer readjust bias for between 1/4 to 1db overbias to find minimum IM distortion point.

2. If bias has been readjusted for this alignment procedure recheck record HF equalization for 0VU at 10KHz.

3. IM Distortion Analyzer can also be used to re-adjust your erase coupling capacitors for minimum IM distortion. This adjustment should be within $\pm 1/2$ turn from that setting selected in step F-2.

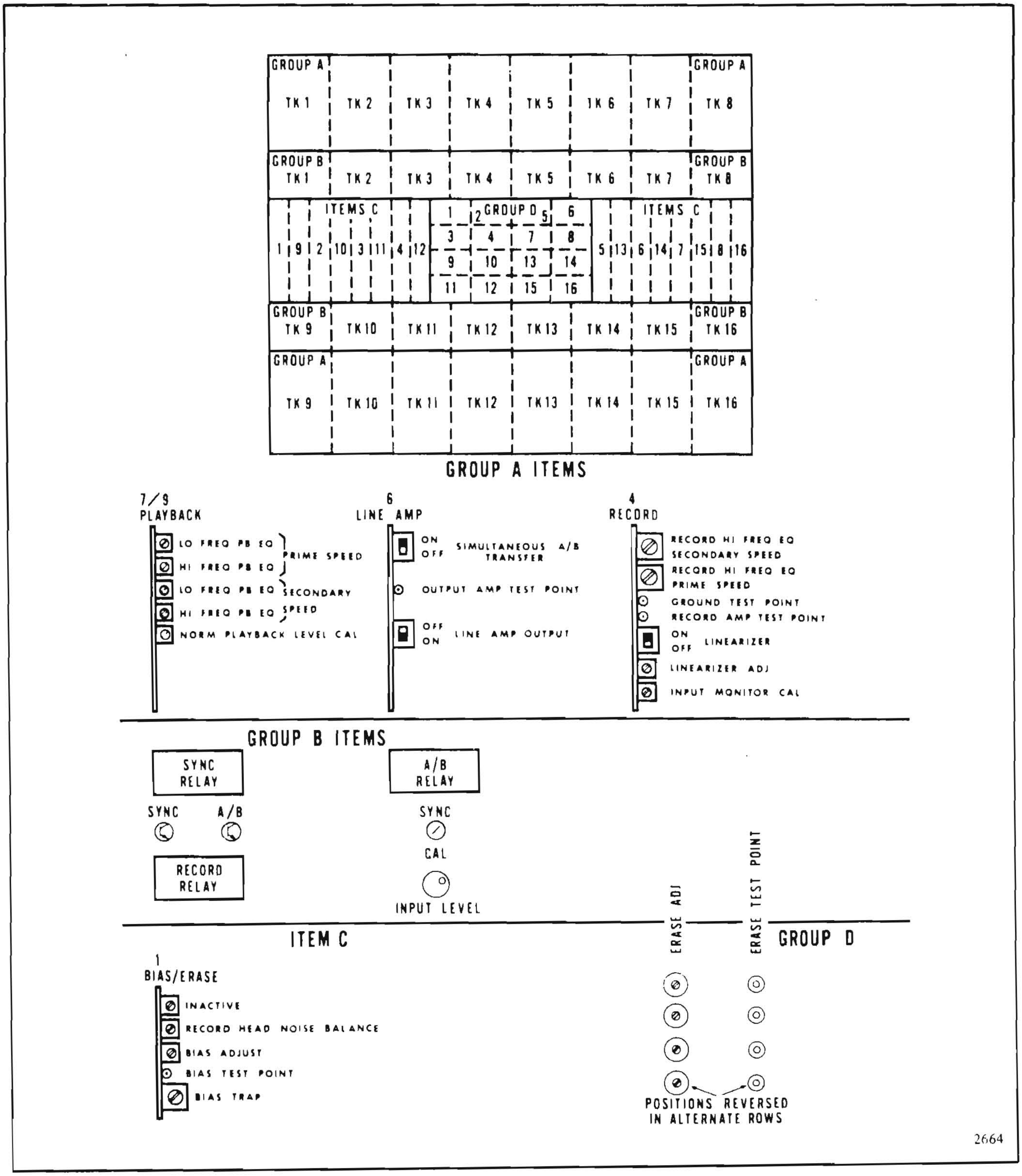

Figure 17. Signal Electronics Adjustment Locations

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SUGGESTED PREVENTATIVE MAINTENANCE SCHEDULE

1. Daily or before each session:

   A. Perform steps:

      a. Visual inspection
      b. Cleaning and degaussing

2. Weekly

   A. Perform steps:

      a. Visual inspection
      b. Cleaning and degaussing
      c. Transport and head adjustments
      d. Playback level and equalization alignment
      e. Record level and equalization alignment

3. Monthly

   A. Perform steps:

      a. Visual inspection
      b. Cleaning and degaussing
      c. Transport and head adjustments
      d. Playback level and equalization alignment
      e. Record level and equalization alignment
      f. Bias and erase circuit alignment

4. Quarterly

   A. Perform steps:

      a. Visual inspection
      b. Cleaning and degaussing
      c. Transport and head adjustments
      d. Playback level and equalization alignment
      e. Record level and equalization alignment
      f. Bias and erase circuit alignment
      g. Noise balance adjustment
      h. Linearizer adjustment
      i. IM distortion adjustments

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TROUBLESHOOTING TIPS

The modular construction of the 3M Brand Series 500 Professional Audio Recorders provide not only a fast and easy method of repair but also an excellent method of troubleshooting. The signal electronics assembly is so arranged in modular form allowing individual circuit boards of any channel to be replaced or exchanged with a similar board from a known good channel. When boards are interchanged, alignment of the channel(s) may be necessary to provide peak performance.

Failure of the recorder to operate properly may be caused by a malfunction in the recorder, or be external causes. Before troubleshooting the recorder, verify that the power and signal connections are correct and that all of the operational controls are properly set.

The best troubleshooting tool is a familiarity with the equipment and a thorough understanding of its theory of operation.

The following paragraphs contain some general precautions which should be observed when performing maintenance on the recorder.

1. Do not strike the reversing idler. It is delicate and located in a vulnerable position at the front of the mechanism. If damaged, flutter will be excessively high.

2. Excerise great care in installing head mounting plates. They can be screwed into place with a head lead pinched between the mounting plate and the transport casting, thus breaking wire insulation or cutting a head lead. Be certain no leads will get in the way before installation.

3. Excerise great care in removing and replacing the mu metal cover over the playback head stack. The slot at the rear cover can slice head lead insulation, thereby grounding head leads or actually cutting through them. Be certain that this cover is fully seated so that the lower lip will not scrape on tape as it passes by. Otherwise tape edge may be cut and bad tracking over the heads may result.

4. Do not go from READY to SAFE when the recorder is operating in the RECORD mode. First stop the transport. This will prevent the possibility of a thump from being recorded on the tape and possible magnetization of the record head.

5. Do not remove any of the electronics cards when the power is on. It requires only a few seconds to turn off the power, remove a card, restore power and be ready to operate. Otherwise, it is possible to magnetize a head or damage a meter.

FIELD SERVICE

Regular scheduled maintenance service is available from the Mincom Division service office on a contract basis. If immediate service is required, it may be obtained on an emergency basis. Every effort is made to furnish the needed repair as soon as possible. For a complete description of 3M's maintenance service plans and their costs, contact the Mincom Division service office.

FACTORY REPAIR SERVICE

If desired, the recorder or major assemblies, may be returned to the factory (transportation prepaid) for repair. When recorder or assembly is returned:

1. Indicate the symptom of defect. State as completely as possible, both on an instrument tag and on the order form, the nature of the problem encountered. Too much information is far better than too little. If the trouble is intermittent, please be specific in describing the instrument's performance history.

2. Give special instructions. If any changes in the instrument or assembly have been made, and it is desired to retain the modified form, please indicate this specifically.

3. To facilitate expeditious repair, your Contract or Purchase Order authorizing the work should be directed to Mincom Division 3M Company 300 South Lewis Road Camarillo, California 93010 -- Attn: Contracts Department.

4. Pack securely and label. Proper packaging saves money. The small amount of extra care and time it takes to cushion a part or instrument properly may prevent costly damage while in transit. Make certain that the address is both legible and complete; failure to do so often results in needless delay. Address all shipments and correspondence to:

   Mincom Division
   3M Company
   300 South Lewis Road
   Camarillo, California 93010

   Attn: Receiving Inspection

5. Show return address on repair correspondence. Please clearly indicate the exact address the equipment should be returned to after repair is completed. Terms are net 30 days f.o.b., Camarillo, California.

Table 7. Troubleshooting Guide

Symptom	Cause	Correction
TRANSPORT		
1. Transport stops when leader passes photo cell V60.	Tape sensor adjustment R73 out of adjustment.	Adjustment R73 in accordance with Tape Sensor Adjustment procedure.
2. STOP button lights when tape is not threaded.	Lamp DS8 burnt out.	Replace DS8.

Table 7. Troubleshooting Guide (Cont.)

Symptom	Cause	Correction
TRANSPORT (Cont.)		
11. Tape lifter hangs up.	Misalignment or in need of lubrication.	Plunger must not drag too forcefully against core of solenoid. Body should be so positioned to avoid such side drag, and to provide best compromise of depth of travel to satisfy easy override yet adequate lifting power.
12. Tape lifter difficult to override manually.	Plunger approaches full seated position too closely.	
13. Tape lifter fails to lift tape from heads.	Plunger operating too far from seated position.	Loosen two mounting screws, lubricate plunger and shift body (holes are oversize) to achieve above requirements.
14. Transport appears completely dead.	Blown fuse F1.	Replace with 5 amps slow blow.
	Intermittent operation of power switch S6.	Press a few times to observe if lights come on.
	C66 charged to greater than 30 volts but no 27 volt dc at collector of Q60 or at test point means Q60 is defective.	Replace Q60 after checking load resistance from collector to ground for short circuit defect. Clear defect before again applying power.
15. All lamps excessively bright and short lived.	Regulator Q60 and associate circuit, Q1, R14, R15, and CR50 not functioning.	Replace Q60. Catcher diode CR51 will also require replacement if condition persisted for more than a few seconds. Check resistance of 27 volt load to be certain Q60 will not be overloaded. Transport may be operated without CR51 until replaced.
16. Flutter and Wow excessive.	Numerous sources possible. Most likely are: a) Insufficient capstan idler pressure either ingoing or outgoing. b) Defective reversing idler. c) Capstan belt tension in need of adjustment. d) Dirty flywheel and motor pulley.	Localize cause of trouble using oscilloscope while referring to Transport Alignment Procedures in this section.
ELECTRONICS		
1. A-B monitor lamps are dim or do not come on when POWER button on transport is pressed.	Short circuit on 28 vdc bus in electronic module assembly.	Remote one plug-in board at a time and re-insert to determine if fault is in cards or module wiring.
	Defective 28 vdc power supply.	Troubleshoot power supply using instruction manual supplied with the unit as a guide.

Table 7. Troubleshooting Guide (Cont.)

Symptom	Cause	Correction
ELECTRONICS (Cont.)		
2. A-B transfer causes clicks in output.	Leaky capacitor C15 in output of record monitor amplifier on board 4 or at output of preamplifier C6 on board 7/9. Also can be leaky input capacitor on line amplifier board 6.	Exchange boards 4, 6, and 7/9 one at a time from known good channel to determine defective board. Troubleshoot defective board looking at capacitors mentioned as being most possible cause of trouble.
3. Loss of signal in record board 4.	Defective field effect transistor Q2. Easily damaged by static charge from soldering iron or tool held in hand.	Replace Q2. Be very careful to avoid static charges. Ground soldering iron to ground bus on board.
4. Noise or intermittent operation in any area of electronics module.	Dirty contacts at base of card plug.	Remove and reinsert board. Use ink eraser to clean contact surfaces.
5. High distortion.	Insufficient bias.	Adjust record bias as prescribed under Signal Electronics Alignment.
	Magnetized head, either record or reproduce head.	Degauss heads.
	Noise balance control misadjusted.	Adjust for minimum noise after degaussing all heads.
6. Poor noise figure.	Noisy Q1 or Q2 on preamplifier board 7/9.	Substitute another preamplifier board to compare noise and replace transistors.
	Head cables badly routed, near hum fields.	Reroute for minimum noise. Keep away from power cord. This can be very important.
	Defective playback head requiring excessive gain.	Try breakin tape if head appears to be smeared over by oxide material. Replace head if necessary.
	Lack of good system ground can produce hum or buzzing. Third wire in power cord not always effective as good ground.	Connect casted frame of transport to good earth ground.
7. Wrong output level.	Improper choice of line impedance or termination.	Check TERMINATION switch position of the channel in question. Output transformer impedance may be changed from normal 600 ohm output to 150 ohms by moving lead from terminal 6 to terminal 4.

PREPRINT NO. 804 (A-6) I

A NEW TAPE TRANSPORT DESIGN

by
James C. Strickland
MCI
Fort Lauderdale, Florida

PRESENTED AT THE
40th CONVENTION
APRIL 27-30, 1971

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A NEW TAPE TRANSPORT DESIGN

Design Considerations

In approaching the design of a new tape transport, a decision had to be made at the outset whether to use the more conventional open-loop or one of the more exotic closed-loop geometries.

The decision was made that the JH-10 transport would stick to proven open-loop design, but with refinements directly attacking certain commonly acknowledged deficiencies of the standard configuration.

The open-loop arrangement is basically characterized by these advantages:

1. Simple tape path.
2. Ample room for heads, shielding, and cabling
3. Easy access for head cleaning, editing, etc.
4. Simple direct tension adjustment
5. Tape path stability

The configuration is also characterized by these disadvantages:

1. Variation in hold back tension of 2.4:1 on a NAB reel
2. Requirement for a "flutter filter"
3. Use of tape tensioning arms

These three disadvantages can be largely offset by direct attack.

Before discussing the corrections applied in these areas, a word about control logic.

Control Logic

Two factors argue in favor of substantial logic in a modern transport. First, the studio trend toward remote control operation. Second, the ease with which compact, modern components allow needed logic to be included. Therefore a complete, foolproof, motion sensing, interlocked logic system of the diode-relay type has been included. See Figure 1. It has last-button precedence and second command memory. Also, guarding is present against spills induced by speed changing and short "flicker" power failures--a real danger to machines with heavy emphasis on dynamic braking. Dynamic braking is complemented by a short pulsing of the mechanical brakes for positive transient control.

Taming the Flutter Filter

The "flutter filter" has traditionally been a problem in fast motion. It makes the machine sluggish and often its residual motion is a nuissance. This problem has been solved by the mechanism pictured in Figure 2. The device is a combination clutch and flywheel brake. It activates in fast motion and during braking following play. When activated the flywheel is lifted away from the clutch plate and braked.

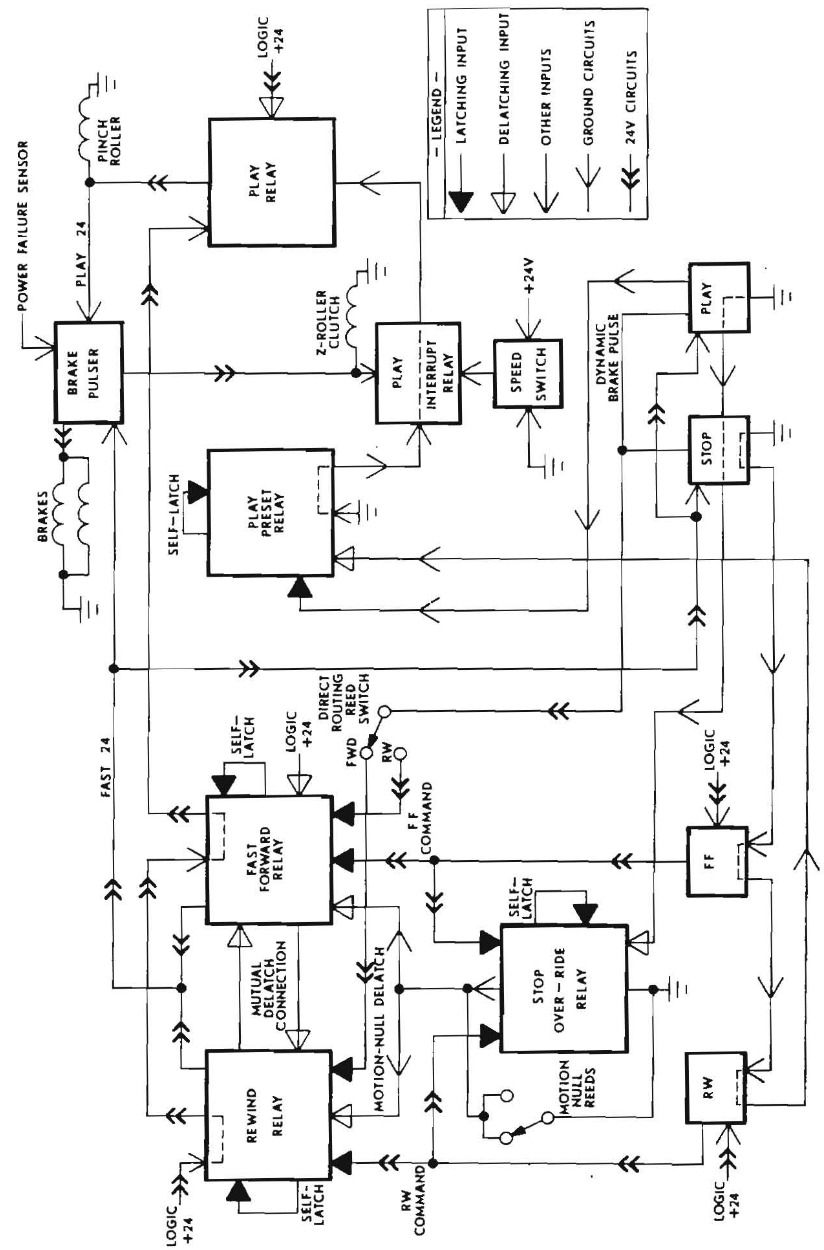


FIGURE 1 JH10 CONTROL LOGIC DIAGRAM

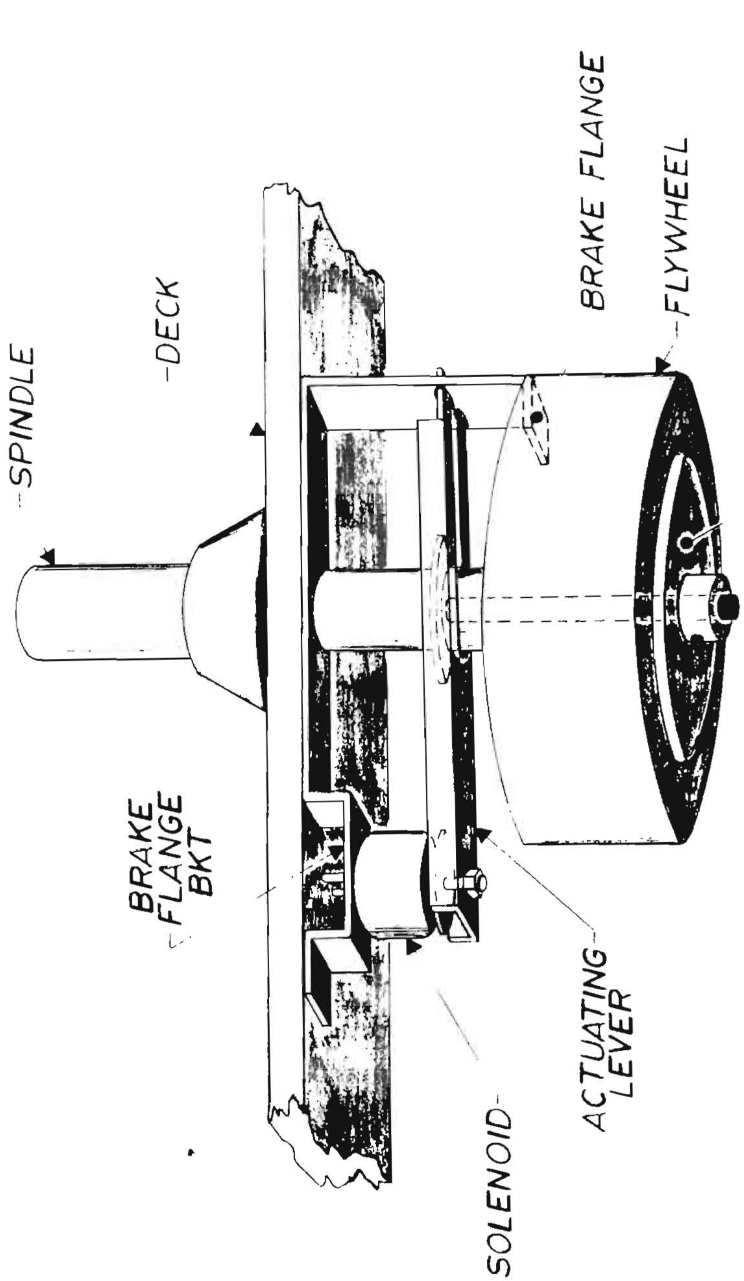


FIGURE 2

Tension-Always a Problem

Tension variation with tape pack has always been a problem with the standard design. It causes: speed variations which compli[illegible]ing, excessive head wear, and wow and flutter variation.

As tape width has grown from ¼" to 1" and 2", new considerations arise. The cost of the heads becomes a substantial fraction of transport cost, thus increasing concern over wear. The difficulty of maintaining good tape path throughout a full reel of tape is enormously magnified. Thus the arguments favoring constant tensioning circuitry make much sense today. Availability of modern silicon components makes the alternative all the more attractive.

However the classic arrangements usually employed for constant tension are not a panacea either. The closed-loop servo type of system has the following traits:

1. Requires mechanical sensing arms
2. Uses DC brush motors
3. Can be plagued by hunting

The mechanical sensor arms pose rigidity and perpendicularity problems which affect tape path and can offset much of the advantage of uniform tension.

Dynamic Torque Control

The system described herein avoids these problems by using phantom sensing to provide open-loop programing of tension. When the capstan in metering tape at constant linear velocity, the angular velocity of each reeling motor is inversly proportional to its instantaneous tape pack radius.

Angular velocity information is acquired from each reeling motor by a 60 aperture strobe affixed to the motor rear shaft. A printed board assembly (see Figure 3) mounts the four reed switches per motor used in the logic circuit and the photo-transistor strobe-reader. The photo-transistor pulses are current amplified on the board and passed on to the input of the dynamic torque control card; see Figures 4 and 5.

Here, digital to analog conversion is accomplished resulting in a negative DC voltage approximately proportional to reeling velocity. This DC signal is used in totality for 15 IPS and divided by two for 30 IPS so that the tension will be the same for 15 or 30 IPS. The DC signal now passes through the empty reel tension control and on to the gate of an N channel FET. Full reel tension control is achieved by source-biasing the FET. The amplified DC at the FET drain is mixed with about ½ volt of 60 Hz AC. The mixed signal is applied to the base of a Darlington connected emitter follower. The emitter load is a Wheatstone bridge consisting of two resistors and two filiament lamps. At a certain DC current in the emitter follower, the bulb resistance will be such that the bridge will be balanced and no differential output will exist. Thus the output from the differential op-amp will be zero. On either side of this balance point the op-amp will put out a signal whose phase (0° or 180°) will depend on the DC level at the emitter follower base.

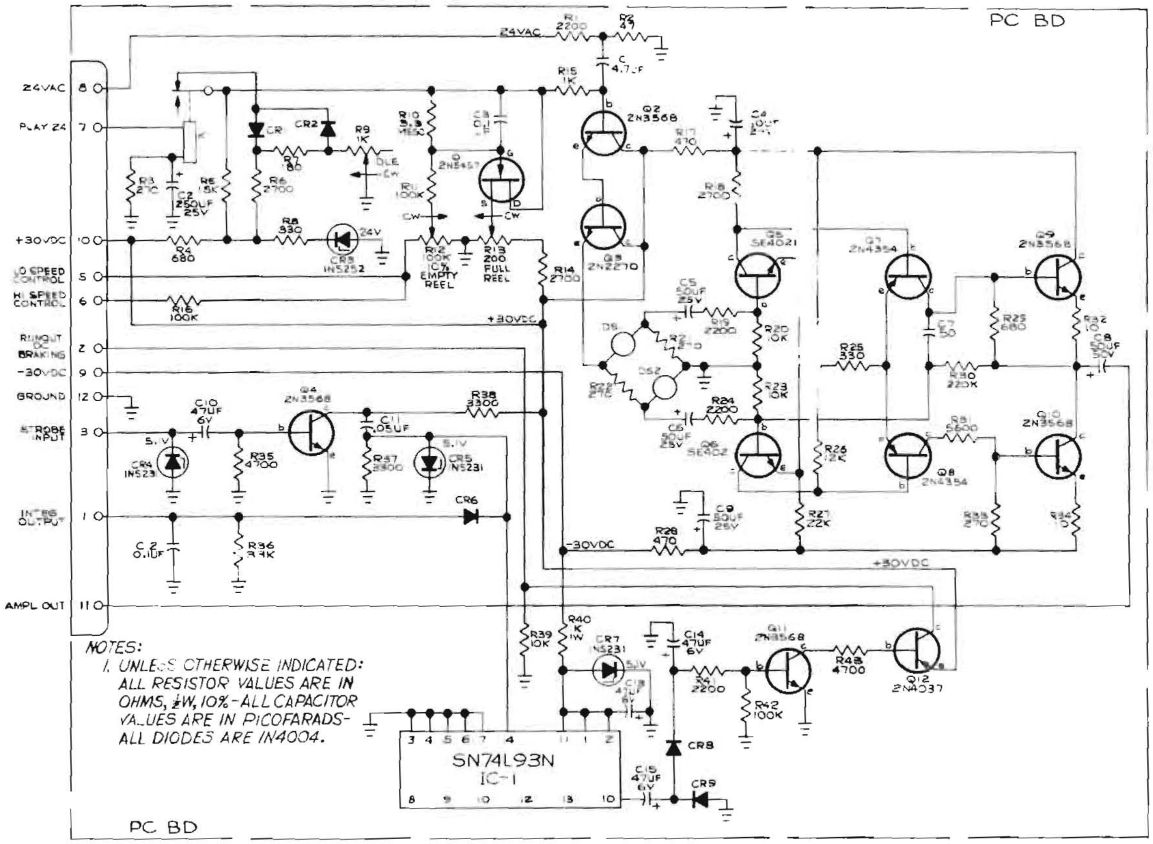


FIGURE 3

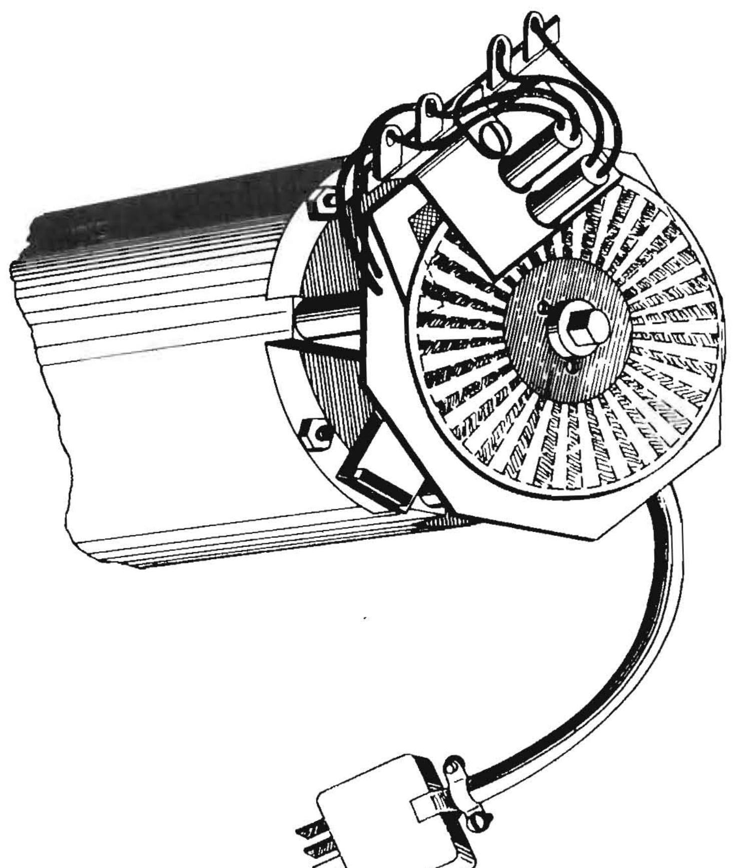


FIGURE 4

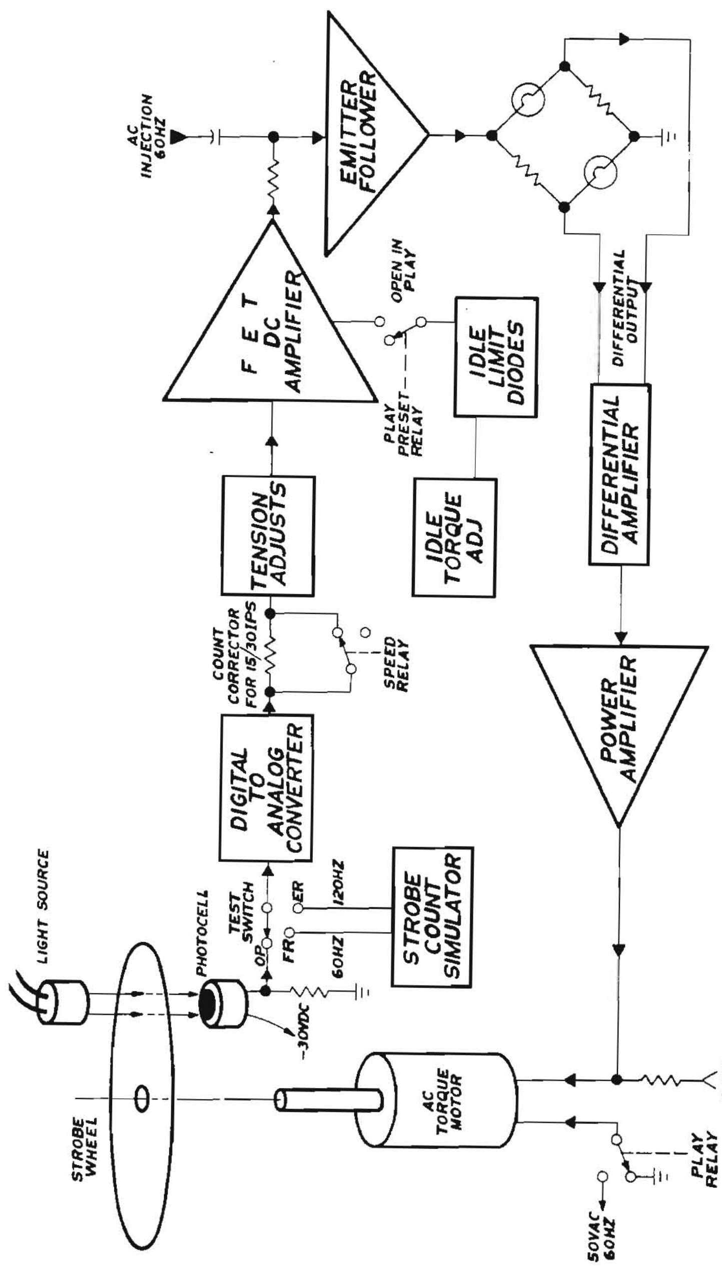


FIGURE 5

This AC output of the op-amp is amplified by a complementary-symmetry emitter follower power amplifier and applied through the logic board to one end of the torque motor windings. In Play, the logic circuit connects the other end of the torque motor windings to a fixed 50 volt AC source. This method results in minimum dissapation and complexity in the amplifiers because only the correction power is developed electrnically and not the total torque motor power of about 70W per motor.

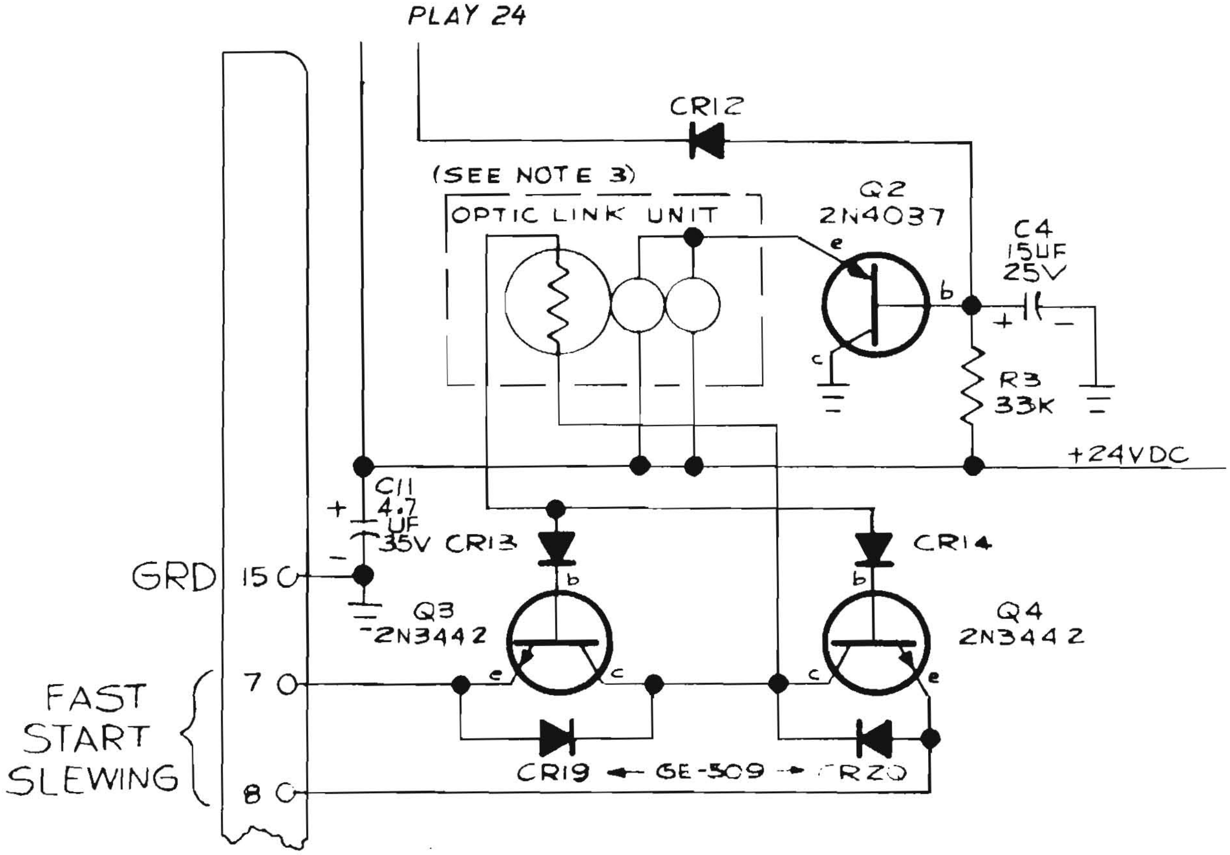
Play tension adjustments require only a screw driver and spring-scale and are conveniently made from the front of the deck. Strobe count values just slightly inside of the extremes produced at empty and full reel situations are simulated by a test switch which injects these signals directly into both torque-control boards. After setting the empty and full reel potentiometers, the tensions will remain with 5% at any tape pack radius. The benefits in the area of speed regulation are sustantial. The total pitch variation in a recorded 15KC tone from full to empty supply reel is ledd than 10 Hz. This is 0.07%. Also tape path and wow and flutter don't substantially change during a whole tape reel.

During threading the 50 volt AC is not applied to the torque motors. The motors are driven only by the amplifiers. In this mode the sensor and amplifier chain function as a closed-loop velocity servo to provide a reeling "Idle" of about one revolution per second. The Idle limit diodes limit Idle torque to prevent spooling once tape is threaded and prevent "back-slope" runaway. By proper selection of the arrangements for the FET voltage supply, the tensions in Play and Idle modes can be made immune to line voltage fluctuations over the rather wide range of 105 to 135 volts. This is effected by the modulator reducing its drive as supply voltages increase.

The dynamic torque system provides runout braking also. The strobe-output signal is digitally divided and rectified to bias on a transistor amplifier chain whenever a persistent velocity exists (even a very slow one). This chain is connected by the logic circuit to the emitter follower power amplifier and applies 30V DC to the motor run winding. This results in smooth positive electronic runout braking with no transistor dissipation once velocity is arrested.

Electronic Fast Start

Elimination of tape-tensioning arms and use of only rigid roller guides is possible because of three factors: dynamic braking, the mild Idle torque present for keeping tape taut during Stop (after the short mechanical brake pulse is complete), and the electronic "fast-start slewing" circuit. Referring to Figure 6, a pair of high-voltage transistors bypass the fast-start resistor which is across pins 7 and 8 or the card which is partially shown. When Play commences, the fast-start relay transfers the take-up motor to this circuit operated from the 117 volt AC line. The timer transistor Q2 allows the lamps of the optic-link isolators to decay over about a three second period. The photo-cell goes to high resistance removing base current from Q3 and Q4, smoothly. This phases out the by-passing effect of Q3 and Q4 on the fast-start resistor. The voltage on the takeup motor will have thus decayed to the point where the fast-start relay can transfer the take-up motor back to the Dynamic Torque Control Circuit without inducing a tape transient.



PLAY 24
CR12
(SEE NOTE 3)
OPTIC LINK UNIT
Q2
2N4037
C4
15UF
25V
R3
33K
+24VDC
C11
4.7
UF
35V
CR13
CR14
GRD
15
Q3
2N3442
Q4
2N3442
FAST
START
SLEWING
7
8
CR19
GE-509
CR20

FIGURE 6

PHONE: 212 392-4010

ASHLAND ELECTRIC PRODUCTS, INC.

32-02 QUEENS BOULEVARD • LONG ISLAND CITY, N. Y. 11101

Audio Engineering Society Tape Recording Seminar Oct. 6, 1971

To be assured of optimum performance of motors and transports, we firmly recommend collaboration between the Engineer designing the tape transport and the motor manufacturer. The motor can be designed in the least uncompromising manner regarding performance, if the motor Engineer has a transport available to him. We urge the approach particularly with regard to capstan motors.

Properly specifying A.C. motors to drive tape transports is easier having facts and handy formulae available.

Within the magnetic saturation limit the locked rotor torque of a motor varies as

$$\left(\frac{E_1}{E}\right)^2 \quad X \quad T = T_1$$

E= Original Design Voltage — T = Torque At Original Design Volts

E_1= Altered Voltage Level — T_1 = Resultant Torque On Altered Voltage

Applying a torque motor of known characteristics to a transport, tape tension can be varied to the desired level and the motor torque immediately determined.

Is the motor safe to operate continuously at the torque and tension desired?

The temperature rise is determined by the change in winding resistance.

$$\frac{RH}{RC} \; (234.5 + T) - (234.5 + T_1) = \text{Deg Centigrade}$$

RH = Resistance after operating at least 1½ hrs

RC = Resistance stablized at ambient temperature

T = Ambient at which RC was taken, in Deg Centigrade

T_1 = Ambient at which RH was taken, in Deg Centigrade

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The allowable total temperature for continuous duty is 105° (Rise plus Ambient).

Because the input power is not changed when operating at 20, 100 or zero RPM it's convenient to restrain the motor shaft, and conduct the temperature rise test.

When required to rewind at full voltage but at a slower speed the motor RPM is governed by:

$$RPM = \frac{F \times T}{1/2\ P}$$

Where F = Frequency in CPS

T = Time in seconds

P = Number of poles

The maximum number of poles in a 24 slot stator for example would be 12 for a 2 phase motor. Actually the more slots per pole the better the motor, but also more expensive. For a 3 phase motor the maximum number of poles would be 8 in the same stator.

When the poles are changed ideally another rotor lamination would provide more optimum characteristics. It is for this reason multispeed asynchronous induction motors are not common. See attached print for example.

The H.P. developed is determined by:

$$H.P. = RPM \times \text{torque (oz-in)} \times 10^{-6}$$

The output in watts is determined by:

$$\text{Watts out} = \frac{RPM \times \text{torque (oz-in)}}{1350}$$

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Reluctance synchronous motors are not practical in multispeed designs. The rotor is very similar to a rotor for an asynchronous machine, except that reluctance paths have either been punched in as a lamination or machined in on the assembled rotor core.

Synchronous motors of the hysteresis type are not effected by the rotor & stator slot combination because the rotor has no slots. Multipseed motors are practical.

In selecting a hysteresis motor usually reference is made to one driving a similar transport, for a starting point.

The motors must have sufficient torque to:

1. Override any torque perturbations in the transport.

2. Prevent any fly wheel from oscillating or hunting due to load or line voltage transients.

The minimum torque that can be used to provide the performance in transport is the ideal approach. When one is concerned with maintaining accurately a series of concentric parts as a motor is, any distortion due to temperature is fatal. Capstan diameters for a direct drive @ 3 3/4 I.P.S. should be held to .0001" run out and .0002" in tolerance. High temperature operation could cause the run out to change far beyond specifications. A typical direct drive capstan motor will have a temperature rise of approximately one degree centigrade per watt @ 3 3/4 I.P.S. Maintaining a low operating temperature assures long life of the bearings and insulation. Tests show 13,200 hrs at an average of 10 lb radial load without periodic lubrication. Even at 2 times the normal capstan puck pressure.

The synchronous torque of a well designed hysteresis motor will vary as the square of the input voltage change. This is true of single speed motors, but not of multispeed motors because the relative magnetic saturation of one rotor energized by two or three pole grouping for two or three speeds is completely different. In practice the rotor is designed so that the minimum cross section of cobalt is used to achieve the desired torque resulting in minimum input power.

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Obviously if 6.oz-in is required at 600 RPM, then the same rotor could not satisfy the requirements for 6.oz-in at 3600 RPM, and a compromise is sought. For this reason we suggest you request from the motor manufacturer torque test data over at least a plus or minus 10% voltage range.

Ideally we prefer to design the motor "on" the transport in our lab.

Using an indirect drive allows the use of 1800 or 3600 RPM motors even for 3 3/4 - 7½ I.P.S. decks. Due to the belt and pulley drive the motor shaft configuration is not as critical. Ten times the HP is practical for indirect drive transports should it be required, as compared to the direct drive.

Lubrication for porus bronze bearing should be applied once every 3-6 months depending on usage. We suggest SAE # 20 non detergent motor oil. Shafts operating in bronze bearings should be hardened to not less than 45 Rockwell C.

Ball bearings used are selected for minimum noise. The higher the ABEC grade of the bearing does not necessarily mean the quieter it is. This should apply to bearings in the transport as well, as the motor.

To be certain of the proper selection of motors for your transport, we suggest you solicit the advice of the motor manufacturer and collaborate on the testing of the equipment.

Carl Berntsen
Carl Berntsen
Chief Engineer

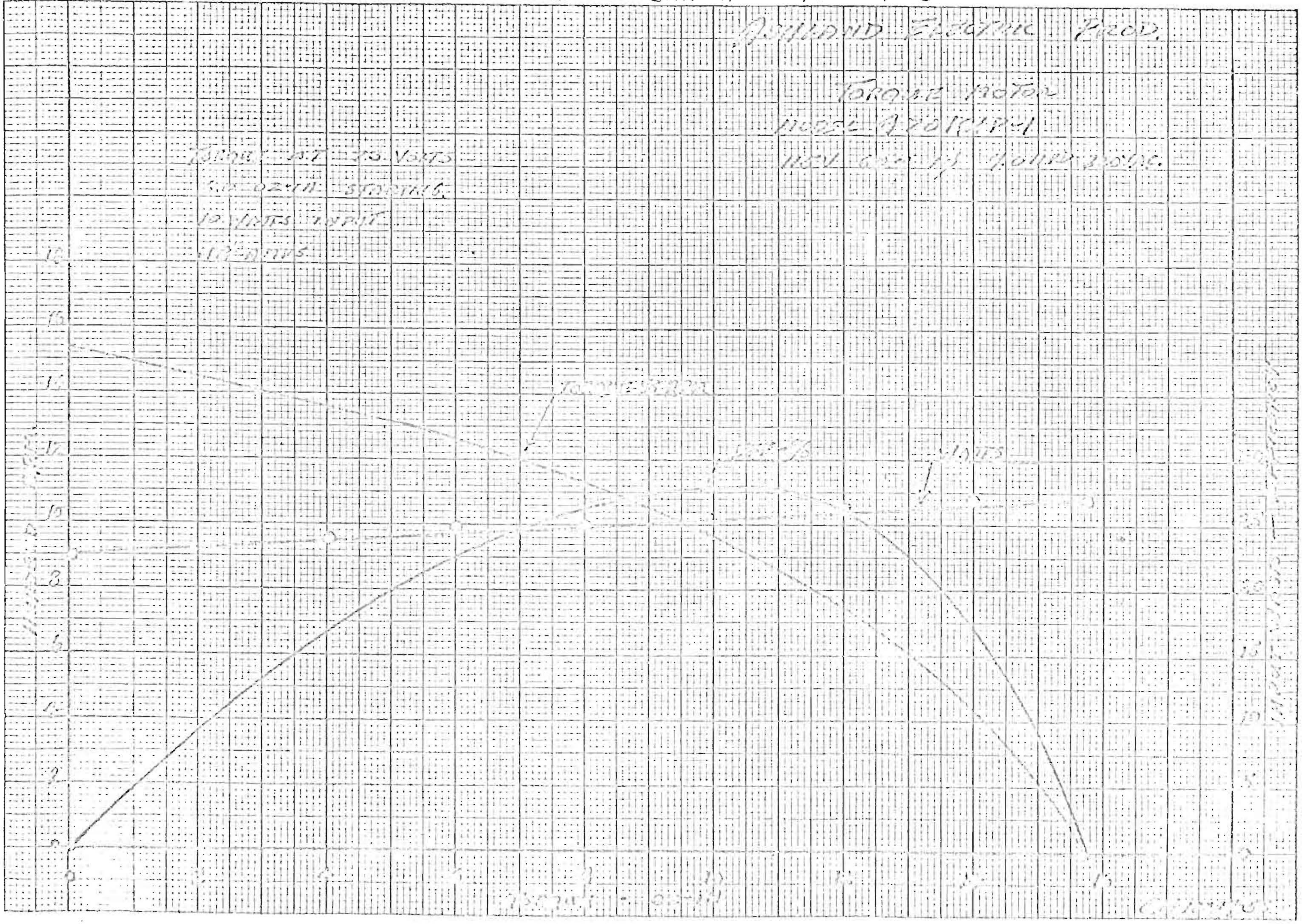
Enclosures:

1. EC 140: Torque/Speed VS Voltage Curves (A96RMP-X1)
2. EC 113: Torque/Speed VS Input (A70KKP-1)
3. Various Lamination Configurations.

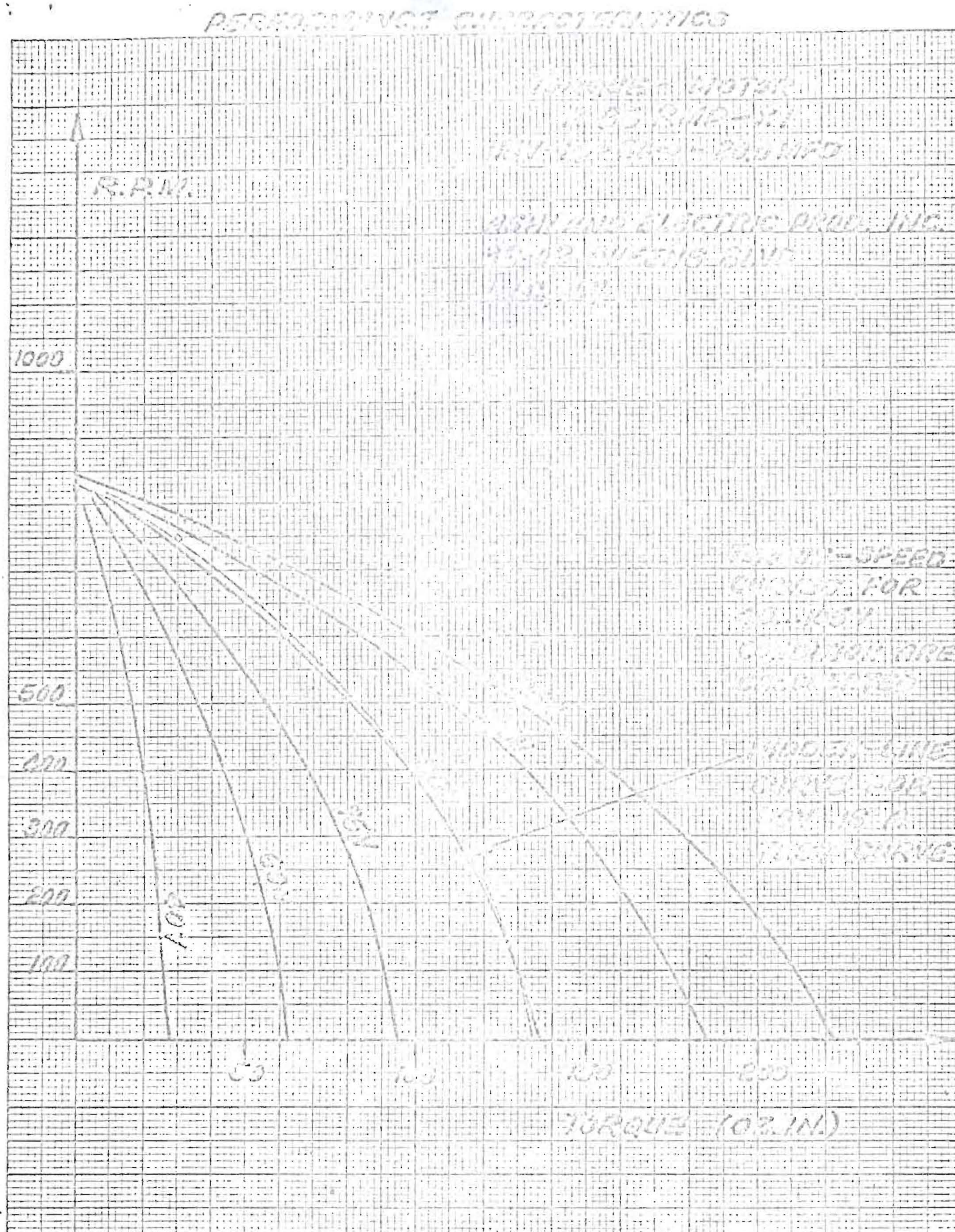
EC-113

KEUFFEL & ESSER CO. MADE IN U.S.A.

PERFORMANCE CHARACTERISTICS



EC-113

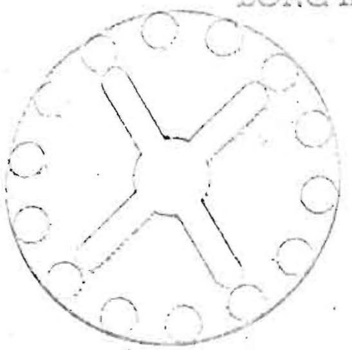


6/12/61

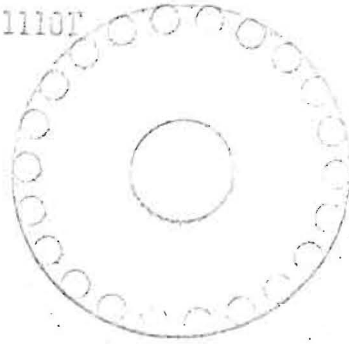
E.C. #140

E.C. #140

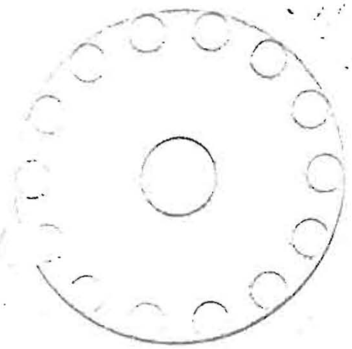
ASHLAND ELECTRIC PRODUCTS, INC.
32-02 QUEENS BLVD.
LONG ISLAND CITY, NEW YORK 11101



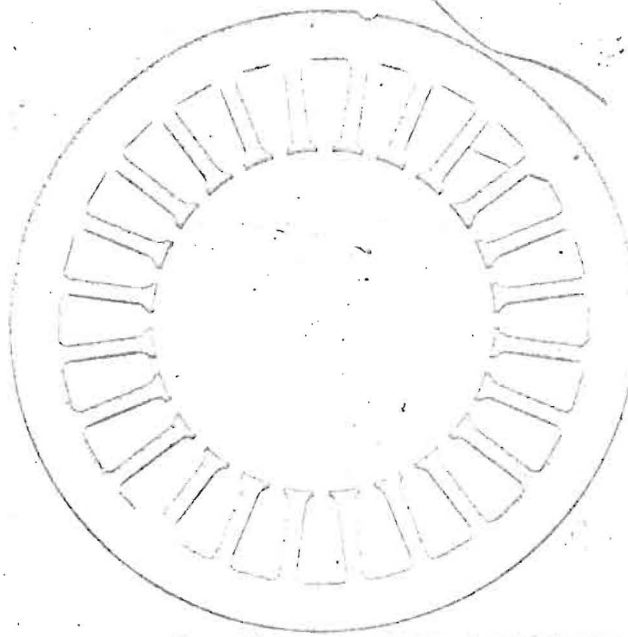
4 POLE RELUCTANCE
ROTOR LAMINATION



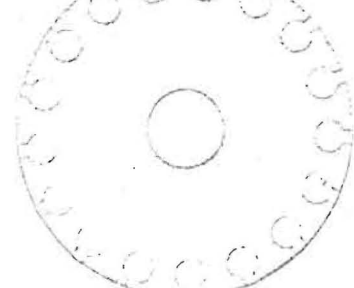
6-8 OR 12 POLE
ASYNCHRONOUS ROTOR LAMINATION



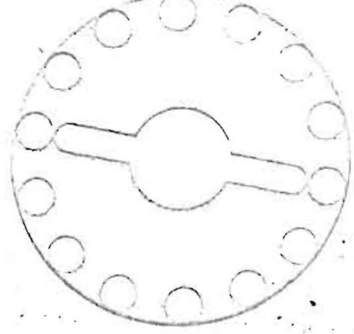
2 OR 4 POLE
ASYNCHRONOUS
ROTOR LAMINATION



24 SLOT STATOR LAMINATION



2 OR 4 OR 12 POLE
ASYNCHRONOUS
ROTOR LAMINATION



2 POLE RELUCTANCE ROTOR LAMINATION

NORTRONICS

TRACK CONFIGURATIONS

"Series" Designations in italics are Distributor equivalents.

1/4" TAPE

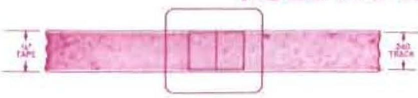
FULL TRACK

ERASE

PR-B1EF *9100 Series*
B1EF *0100 Series*
LMEF *4400L Series*
SMEF *4400 Series*

RECORD/PLAY

PR-B1F *9100 Series*
SLF *4100 Series*



2 CHANNEL—2 TRACK

ERASE

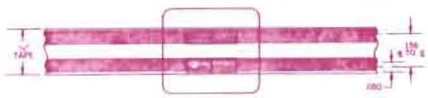
B2EH *8300 Series*
LSEH *2200L Series*
SSEH *2200 Series*
PR-B2EH *9200 Series*

RECORD/PLAY

PR-B2H *9200 Series*
WP-B2H *8200 Series*
P-B2H *2000 Series*
B2H *1000 Series*
C2H

COMBO

P-A2H *6100 Series*
A2H



2 CHANNEL—4 TRACK

ERASE

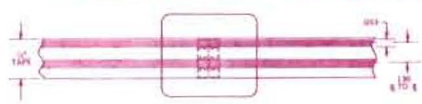
B2EQ *8700 Series*
SSEQ *1400 Series*
LSEQ *1400L Series*

RECORD/PLAY

WP-B2Q *8600 Series*
P-B2Q *1200 Series*
B2Q *1000 Series*
C2Q

COMBO

P-A2Q *6000 Series*
A2Q



3 CHANNEL—3 TRACK

ERASE

PR-B1EF / B1EF / SMEF / LMEF (for erasing all 3 channels simultaneously)* *See Distributor equivalents above

RECORD/PLAY

P-B3Q *5700 Series*

4 CHANNEL—4 TRACK

ERASE

Independent Channel Erasure*
SSEQ / LSEQ — 2 staggered

For erasing all 4 tracks simultaneously*
PR-B1EF
B1EF
SMEF
LMEF
*See Distributor equivalents above

RECORD/PLAY

P-BQQ *5600 Series*
BQQ
BQQN

2 CHANNEL—8 TRACK

ERASE

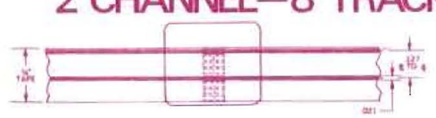
use PR-B1EF
B1EF
SMEF
LMEF
for erasing all tracks simultaneously*
*See Distributor equivalents above

RECORD/PLAY

B2L *5800 Series*

COMBO

ZJ2L *6800 Series*



4 CHANNEL—8 TRACK

ERASE

use PR-B1EF
B1EF
SMEF
LMEF
for erasing all tracks simultaneously*
*See Distributor equivalents above

RECORD/PLAY

P-BQL *5830 Series*

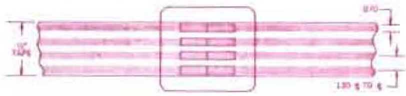
STUDIO SERIES

1/2" TAPE — 3 CHANNEL—3 TRACK

ERASE
STE-3
RECORD *9300 Series*
STR-3
PLAYBACK
STP-3

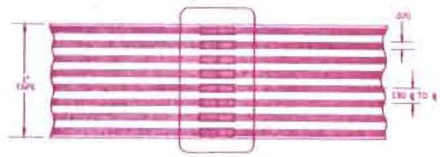
4 CHANNEL—4 TRACK

ERASE
STE-4
RECORD *9400 Series*
STR-4
PLAYBACK
STP-4



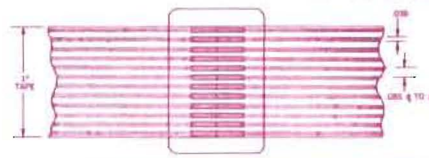
1" TAPE — 8 CHANNEL—8 TRACK

ERASE
STE-8
RECORD *9800 Series*
STR-8
PLAYBACK
STP-8



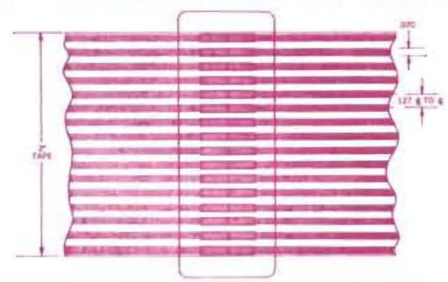
12 CHANNEL—12 TRACK

ERASE
STE-12
RECORD
STR-12
PLAYBACK
STP-12



2" TAPE — 16 CHANNEL—16 TRACK

ERASE
STE-16
RECORD
STR-16
PLAYBACK
STP-16



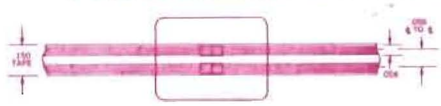
CASSETTE

.150" TAPE — 1 CHANNEL—2 TRACK

ERASE
W1ER *5140 Series*
RECORD/PLAY
W1R *5130 Series*

2 CHANNEL—2 TRACK

ERASE
W2ER *5210 Series*
RECORD/PLAY
W2R *5200 Series*

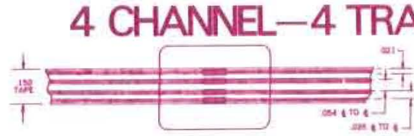


2 CHANNEL—4 TRACK

ERASE
W1ER *5140 Series*
RECORD/PLAY
W2J *5230 Series*
COMBO
ZW2J *5260 Series*

4 CHANNEL—4 TRACK

ERASE
W2ER *5210 Series*
RECORD/
W4J *5400 Series*
COMBO
ZW4J *5410 Series*



NORTRONICS

magnetic recording reference list

As a service to its customers, **Nortronics** presents a list of publications and books dealing with the theory and practice of magnetic recording. The complete technical library should be stocked with all or most of the following titles.

RECORDING THEORY AND PRACTICE (SEMITECHNICAL)

ABC'S OF TAPE RECORDING. Crowhurst. 96 pp. Nontechnical. *(Howard Sams Publication No. 20395)* $1.50

TAPE RECORDING FOR THE HOBBYIST. Zuckerman. 160 pp. 1968 *(Howard Sams Publication No. 20593)* $3.95

TAPE RECORDERS – HOW THEY WORK. Westcott & Dubbe. 234 pp. 1964. Excellent general-purpose semi-technical reference for audio recorders. Goes into motors, heads, circuits, equalization, etc. *(Howard Sams Publication No. 20290)* $2.50

PRACTICAL GUIDE TO TAPE RECORDERS. Audell's. 277 pp. 1965 *(Howard Sams Publication No. 60127)* $4.95

RECORDING THEORY AND PRACTICE (TECHNICAL – GENERAL)

MAGNETIC RECORDING TECHNIQUES. Stewart. 270 pp. 1958. Basic reference and text. *(McGraw-Hill)*

MAGNETIC TAPE RECORDING. Spratt. 369 pp. 1964. Basic reference and text. *(Temple Press Books Ltd., London, England)*

PHYSICS OF MAGNETIC RECORDING, VOL. II. C.D. Mee. 270 pp. 1964. Fundamental theory and concepts, much on magnetic tape. *(John Wiley & Sons)*

MAGNETIC TAPE RECORDING. Athey. 326 pp. 1966. Mostly on instrumentation recording, with many photos and descriptions of specialized recorders for space probes, etc. *(NASA No. SP-5038, National Aeronautics and Space Administration, Washington, D.C.)* Order from: U.S. Government Printing Office, Washington, D.C. 20402. $1.25

MAGNETIC RECORDING IN SCIENCE AND INDUSTRY. Pear. 450 pp. 1967. Principles, recording media, transports, accessories, analog, digital, drums, discs and control applications. *(Reinhold Publishing Corporation, New York)* $19.50

DIGITAL MAGNETIC RECORDING. Albert Hoaglund. 154 pp. 1963. Theory of magnetic recording as applied to the digital field; media, mass storage, heads, writing, reading, etc. With mathematical treatment. *(John Wiley)*

MAGNETIC TAPE INSTRUMENTATION. Gomer Davis. 263 pp. 1961. Instrumentation and digital recording. Basic reference. *(McGraw-Hill)*

MAGNETIC RECORDING HANDBOOK. Howard and Ferguson. 50 pp. 1966. Application notes on FM recording. *(A.N. 89, Hewlett Packard, Mountain View, California 94040)*

MAGNETIC RECORDING THEORY FOR INSTRUMENTATION. Lowman and Angerbauer. 112 pp. 1963. Application Notes and Theory on analog and digital recording. Used as basis of a course on instrumentation recording theory. *(Ampex Corporation Training Department, Redwood City, California 94063)*

CIRCUITRY FOR MAGNETIC RECORDING

TRANSISTOR AUDIO AMPLIFIERS. Dwight Jones and Richard Shea. 267 pp. 1968. Basic theory of transistors and FET's, amplifiers, equalization and feedback, plus practical operating circuits. Includes an excellent section on tape recording amplifiers and functional circuits on stereo recording and playback amplifiers. *(John Wiley & Sons)*

ELEMENTS OF TAPE RECORDER CIRCUITS. Herman Burstein. 223 pp. 1966. *(Gernsback Library)*

HANDBOOK OF TRANSISTOR CIRCUITS. Alan Lytel. 200 circuits on counters, timers, flip-flops, amplifiers, oscillators, etc. *(Howard Sams Publication No. 20399)* $5.50

INDUSTRIAL TRANSISTOR CIRCUITS. 111 pp. 1968. *(Howard Sams Publication No. 20245)* $2.75

VIDEO RECORDING

VIDEO RECORDING. Julian Bernstein. 268 pp. 1960. Semi-technical basic reference. *(John F. Rider Publications)*

TELEVISION TAPE RECORDING FUNDAMENTALS. Harold Ennes. 256 pp. *(Howard Sams Publication No. 20065)* $5.95

SERVICING AND REPAIR OF RECORDERS

TAPE RECORDER SERVICE MANUAL AND TROUBLESHOOTING WORKBOOK. Robert Marshall. 128 pp. 1962. *(Chilton Company, Philadelphia)*

"TR" TAPE RECORDER SERIES MANUALS. Over 50 service manuals (TR-1, TR-2, etc.) issued on a continuing basis, from 1958 to present, covering U.S. and foreign reel-to-reel, Cartridge and Cassette record/playback (not play-only) machines. Each volume has complete index by models of all recorders covered previously. *(Howard W. Sams & Company, Indianapolis, Indiana)* $4.95 each

SERVICING AND REPAIR OF RECORDERS

"HTP" SERIES, HOME TAPE PLAYER SERVICE MANUALS. (HTP-1, HTP-2, etc.) This manual series covers machines which play pre-recorded tape cartridges, but which do not make recordings. Included are those using the endless-loop 8-Track Stereo ("Stereo-8") and 4-track stereo cartridges, plus the CASSETTE type reel-to-reel cartridge players. Home players only are covered – see Auto Radio series below for automobile tape players. *(Howard W. Sams)* $4.95 each

"AR" SERIES, AUTO RADIO AND TAPE PLAYER SERVICE MANUALS. (AR-1, AR-2, etc.) Covers Cartridge and Cassette type auto tape players along with radios. Each manual has complete index by model. *(Howard W. Sams)* $4.95 each

NORTRONICS TAPE HEAD REPLACEMENT AND CONVERSION GUIDE. 6TH EDITION. Full listing of thousands of U.S. and foreign tape recorders by model numbers, with recommended NORTRONICS replacement or conversion heads. Also cross-indexed by original head part number, showing equivalent NORTRONICS head model. *(NORTRONICS COMPANY, INC., 8101 10th Avenue North, Minneapolis, Minnesota 55427)* $5.00 for Complete Guide. Free for Condensed Guide.

STANDARDS – MAGNETIC RECORDING

NAB REEL-TO-REEL MAGNETIC TAPE RECORDING AND REPRODUCING STANDARD. 30 pp. 1965. *(National Association of Broadcasters, 1771 N-Street N.W., Washington, D.C. 20006)*

NAB CARTRIDGE TAPE RECORDING AND REPRODUCING STANDARD. 27 pp. 1964. Two and three-channels on 1/4-inch tape cartridges for radio station applications. *(Above address)*

RIAA STANDARDS FOR MAGNETIC TAPE RECORDS, E-5. 4 pp. 1969. Covers primarily home entertainment 1/4-inch pre-recorded tapes; reel-to-reel and endless-loop cartridges. Two, four, and eight-track dimensional information is presented. *(Record Industry Association of America, Inc., One East 57th Street, New York, New York 10022)*

IRIG TELEMETRY STANDARDS NO. 106-66. March, 1966. *(Defense Documentation Center for Scientific and Technical Information, Cameron Station, Alexandria, Virginia 22314)*

"DIN" GERMAN INDUSTRIAL STANDARDS (Deuche Industrie Normen). Complete series of European standards on tape, heads, system performance, etc. In German, with many items available in English Translation. Write to: USASI, 10 East 40th Street, New York, New York 10016 for listing and prices.

LIST OF PUBLISHED STANDARDS RELATING TO MAGNETIC SOUND RECORDING. March, 1966. Fairly complete listing which includes S.M.P.T.E. standards on 8 mm., 16 mm. and 35 mm. magnetic sound stripe, plus various foreign and U.S. Government standards. *(J.G. McKnight, AMPEX CORPORATION, P.O. 1166, Los Gatos, California 95030)*

1. TEST TAPE APPLICATIONS. 2. LEVEL AND FREQUENCY RESPONSE STANDARDIZATION IN MAGNETIC SOUND RECORDING. Morrison and McKnight, 1967. Two pamphlets with articles reprinted from the Journal of the Audio Engineering Society. *(Ampex Corporation, P.O. 1166, Los Gatos, California 95030)*

(Electronic Industries Association, 2001 Eye Street N.W., Washington, D.C. 20006) Minimum $1.00 per order:

RS-288 AUDIO MAGNETIC PLAYBACK CHARACTERISTICS AT 7-1/2 IPS. 1963. $0.50

RS- CP-II. (EIA Co-Planar Type II.) CASSETTE TAPE CARTRIDGE STANDARDS. Under consideration; to be issued in 1970.

RS-264 MAGNETIC RECORDING TAPE CARTRIDGE DIMENSIONS. (Endless-loop type). 1962. $0.50

RS-224 MAGNETIC RECORDING TAPES. 1959. $0.60

RS-332 DIMENSIONAL STANDARDS – ENDLESS LOOP MAGNETIC TAPE CARTRIDGES, TYPES EL-1, EL-2, and EL-3. 1967. $1.60

RS-342 MAGNETIC TAPE, ELECTRICAL RESISTANCE COATING, RECOMMENDED TEST METHOD OF. 1967. $1.40

RS-346 TYPE A REELS AND HUBS FOR MAGNETIC TAPE. 1968. $0.80

RS-347 1/2 INCH TYPE B PLASTIC REEL. 1968. $0.80

RS- EIA OPEN REEL REPRODUCER TEST TAPE. (From S.P. 1030) For 7.5 and 3.75 ips tape speeds, includes reference level, azimuth and frequency response measurement sections. To be issued in 1970.

RS-338 STANDARD FOR UNRECORDED MAGNETIC TAPE FOR REEL-TO-REEL INSTRUMENTATION. 1967. $0.50

RS-362 TENSILE PROPERTIES OF MAGNETIC TAPE – TESTS. June, 1969

Nortronics COMPANY, INC.
8107 Tenth Avenue North Minneapolis, Minnesota 55427
Phone: (612) 545-0401

THIS FORM SUPERSEDES ALL PREVIOUSLY PRINTED No. 7288 FORMS PRINTED IN USA FORM NO. 7288 D

Sound Talk®

A Technical Service to the Industry from the makers of Scotch Magnetic Tape

Volume I
No. 1
1968

DESIGN CONSIDERATIONS TO INSURE INTERCHANGEABILITY OF RECORDING TAPE

As the variety of magnetic recording tapes increases, questions are being asked about tape similarities and differences. What are the basic differences between the popular types of tape? Is it possible to interchange the different types of tape without sacrificing performance? How can I achieve maximum performance from my recording system using a specific tape?

Because of the large variety of professional and home recording systems, each of them built to individual manufacturing specifications with different settings and adjustments, it would be impossible to list all the specific differences for each system. Quality magnetic recording tape is manufactured to established specifications and its performance is predictable and easily measured. Reviewing some of the individual properties and characteristics of recording tape will show us what the tape is capable of reproducing with specific inputs. Observing some of the similarities and differences in performance will show some of the requirements for optimization of the recording system to take advantage of the individual characteristics of each tape.

For convenience this paper will cover the three most popular types of magnetic recording tape.

We will consider "standard" recording tape as a reference and will use it as a basis of comparison for the other tapes.

Classification	*Example of Commercial Number*
Standard	#111, 102
Extra-play	#150, 190 & 200
Low Noise	#201, 202, 203

TAPE PROPERTIES

Magnetic recording tape receives and retains magnetic signals from the recorder head. The thin layer of ferric oxide, coated on a polyester or acetate backing is the substance that reacts to magnetic signals. The magnetic properties of an oxide coating are the basic factors which determine the differences between tapes. Certainly, the thickness of the oxide coating, the application and purity of the oxide, particle size and orientation, and the type and thickness of the backing are all variables, but for this discussion we will be concerned with the magnetic properties. Future *SOUND TALK* Papers will explore the types of backing and the physical parameters of tape more completely as separate subjects.

The parameters which identify the fundamental magnetic differences between tapes are the intrinsic magnetic properties of Coercivity, Retentivity, and Remanence. The intrinsic magnetic properties are the measurements of magnetic flux interaction with the tape's coating; and the coatings ability to receive and retain the magnetic signal.

COERCIVITY

As a strict definition, coercivity is a measure of the magnetic flux intensity required to return a magnetic material from saturation back to zero. Practically speaking, it represents the flux intensity or magnetic field strength required to record a magnetic signal onto the tape. A high coercivity tape requires a greater flux intensity (a higher signal and bias level from the recorder head) to record on the tape. An example is low noise tape which

has a coercivity measurement of 315 oersteds (a unit of measure of magnetic field strength). In comparison, standard tape has a coercivity measurement of 270 oersteds which indicates a lower flux density is required to record on this tape. The extra-play tape has an even lower coercivity of 260 oersteds which shows that this tape will respond to an even lower flux density level. The coercivity of a tape is a function of the basic oxide particles used to form the dispersion that will ultimately become the coating. Coercivity, therefore, is a measure of the magnetic field strength required to establish magnetism in the coating.

RETENTIVITY

Now that we have magnetized a section of tape with a signal from the recorder head, the next tape parameter is concerned with how much of the signal, in terms of magnetic strength, is retained in the tape coating the instant it leaves the influencing field of the recorder head. This is known as Retentivity; which is the measurement of the number of flux lines (or gauss) per square centimeter of the coating cross section (width of tape and the coating thickness).

Although some tapes respond to a magnetizing signal output more readily than others, they all will retain the resultant magnetic impulse indefinitely. Retentivity is primarily a magnetic property of the coating dispersion (particle size, density, and composition) without reference to the tape size, and it varies with the particular coatings used for recording tapes. A typical retentivity measurement for standard tape is 920 gauss (a unit measure of magnetic induction or quantity value of magnetic flux). The dispersion used for a low noise tape has a retentivity of 790 gauss which is lower than standard tape. The extra-play tape has an extremely high retentivity of 1120 gauss. Each dispersion used in the manufacture of the three basic tapes has a different value of retentivity. This value however, defines one of the properties of the dispersion before being coated onto a backing. A more meaningful measurement to the user would take into account the result of applying the dispersion in a given thickness to a particular width of backing. Since the majority of recorders use a ¼" wide tape, the industry developed a parameter with the ¼" as a constant. This is known as remanence. Since the tape width is a constant, the two immediate variables are coating thickness and dispersion type.

REMANENCE

Remanence is the actual magnetic signal retention as applied to a specific tape cross section. For our purposes, we will regard remanence as the induced magnetic flux remaining in a ¼" wide tape after a longitudinally applied field is reduced in intensity from 1000 oersteds to zero. This is explained simply by saying that a ¼" wide tape will have retained the recorded magnetic signal and will exhibit a magnetic field of its own. The remanence property therefore, is what the playback head is magnetically exposed to

As previously shown the retentivity of the three basic oxide dispersions are all quite different. From this, one might expect different results in terms of playback. But, by carefully controlling the application of the coating, the remanence value can be established at a desired point. To assure proper interchangeability of the three tape types, the coating variables are structured so that the remanence value is the same for all three tapes. EACH OF THE THREE TAPES HAVE A REMANENCE MEASUREMENT OF 0.64 FLUX LINES PER ¼ INCH WHICH ASSURES A MAGNETIC COMPATIBILITY AND PLAYBACK INTERCHANGEABILITY BETWEEN ALL OF THE THREE TAPES. While the control of the remanence value allows the tapes to be interchanged, the differences in coercivity and oxide retentivity require slightly different magnetic signal input levels during recording to fully exploit the abilities of the different tapes. Some of the differences that the tapes exhibit and the corresponding machine adjustments for maximum performance will be shown in the following paragraphs.

TAPE CHARACTERISTICS

The differences in the magnetic properties are reflected in the particular characteristics which each tape exhibits. Assuming a tape speed of 7.5 ips, some of the characteristic differences can be easily shown in the frequency response curve for each tape (Figure 1). These curves were generated on a good quality professional machine and show the difference in both the low and the high frequency response. To establish these response curves, the recorder was adjusted for maximum performance using the standard type of tape. The record level, bias, and record equalization were set to achieve the best response possible from this machine with standard tape. The individual magnetic properties of each different tape became apparent in the differing output and response when each is run without readjusting the machine.

RESPONSE

The ideal response curve would assume a straight line from the low to the high frequencies, but is limited by the recorder electronics. Note that the standard tape (which had the optimum settings) is nearly level until

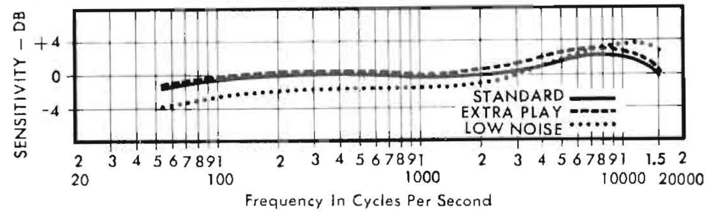


FIGURE 1. FREQUENCY RESPONSE — TAPE AND RECORDER

the high frequency roll off. The extra-play tape, with slightly lower coercivity, shows a slight increase in high frequency response but has a sharper roll off. The high coercivity, low noise tape shows a slight decrease in sensitivity at low frequencies but has a prominent increase at the high frequencies with less roll off. Figure 1 shows only a comparison of typical response for the three tapes, but from our discussion of coercivity, one will remember that each tape required differences in the input signal level. The desired frequency response for either high or low frequencies, *for each particular tape*, can be achieved by changing the bias and record equalization levels. Variations in the bias and equalization settings and the corresponding changes in output will be shown in later paragraphs.

It is possible to design a recording tape for maximum output at either high frequencies (short wavelength) or low frequencies (long wavelength) by formulating different coating dispersions. Variables would be coating thickness, coercivity, and retentivity. In the design of Audible Range Magnetic Tape the challenge lies in the ability to produce a tape that is capable of uniform output over the broad range of wavelengths from less than ½ mil to more than 30 mils. A factor which can affect response is the smoothness of the surface coating. A very smooth coating surface insures maximum contact with the recorder head therefore allowing a maximum of magnetic signal changes to interact on the tape. Minute variations in the coating surface, as found occasionally in low quality recording tapes, will create variations in the head-to-tape contact which will change the magnetic flux level and will affect the playback signal from the tape to playback head.

While discussing tape response, it would be well to mention that recording tape sees the recording in terms of wavelength and not frequency. This is understandable when one considers that there are two variables that affect the recording process. One is the frequency that is being recorded, the other is the relative speed of the tape passing the recording head. Suppose that a tape is travelling at 7½ ips, and that a 7.5 kHz signal is being recorded. This means that 1000 cycles of information are packed on each inch of tape. The distance encompassed by each complete cycle is 1/1000 inch. The wavelength of this recording is 1 mil.

Expanding the previous example, we find that doubling the frequency 15 kHz will cause 2000 cycles of information to be placed on each inch of tape. This renders a recorded wavelength of ½ mil, as each individual cycle takes up .0005 inch of tape. If we reduce the tape speed to 3¾ ips, and leave the frequency to be recorded at 7.5 kHz, we once again will be recording a ½ mil signal. If both the frequency and the tape speed are doubled, the tape will see no change in recorded wavelength.

Since the information is recorded on the tape coating magnetically, it could be viewed by applying a fine metallic powder to the tape and viewing it with a magnifying glass (Figure 2). Notice the variations in magnetic pole density, the low frequencies are widely spaced (long wavelength) and the high frequencies are packed very close together (short wavelength). When recording at the short wavelengths, the coating which becomes *magnetized for each cycle* of information; must faithfully establish each set of poles without disturbing the preceding pole. When the magnetic poles are very close together the coating's ability to receive and hold magnetization (coercivity and retentivity), without influence from adjacent magnetic fields is very important. The oxide dispersion must be carefully prepared and applied to assure correct coating caliper, coating density, coating surface smoothness, as any variations will create changes in the magnetic properties and the sensitivity.

FIGURE 2. MAGNETIZED PORTION OF RECORDED TAPE

SIGNAL TO NOISE

Another important tape characteristic is the signal to noise ratio. Tape noise is strongly influenced by the particular type of oxide coating. Specially designed low noise oxide and precise manufacturing control allows the production of tape with a greatly improved signal to noise ratio. A comparison of standard and low noise tape shows a difference of 6 db at 500 cps to the upper limits of the audible spectrum (Figure 3). Low noise tape, as you recall from earlier paragraphs, has a high coercivity coating. This is a basic property difference of the special low noise oxide. Tape noise is a very low level signal and may be masked by the recorded sounds but does become critical during quiet musical passages. This extension of the dynamic range is important for full fidelity enjoyment. For maximum purity of reproduced sound, the use of low noise tape is recommended. In addition to the benefit of noise reduction, the coating properties of this tape give greater fidelity and response in the high frequency region of recording.

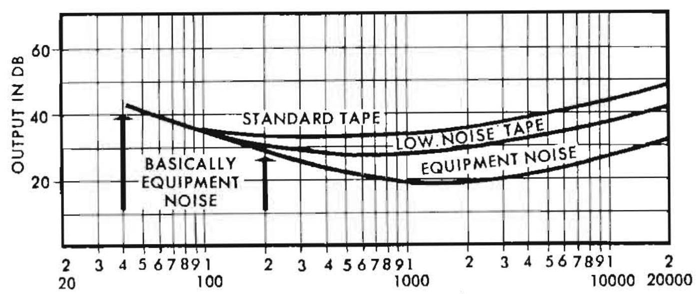


FIGURE 3. NOISE BY ⅓-OCTAVE BANDS

PERFORMANCE

Because of the different coatings available, magnetic tape is manufactured to meet a variety of recording requirements. Although the Audible Range constitutes a challenge because of the frequency bandwidth, an important factor is the production of tapes which are

compatible to each other on the large variety of recording systems available. As previously shown, each particular type of tape has its individual magnetic properties which respond, in terms of maximum performance, to specific input levels.

BIAS

Figure 4 shows a typical example of optimized bias settings for each of the three tapes. Some of the recorders now in use have a fixed bias level which cannot be changed, but the majority of them offer some control over bias level. As part of the basic design, each recorder manufacturer establishes a bias level which is adjusted for a particular recording head and a laboratory tape. On any recorder care should be taken in making bias adjustments, and the recommendations of the recorder manufacturer should be followed. Professional recorders have specific adjustments for bias and equalization, and these adjustments can be made with more ease. Because of the large variety of recorders available, each with their own specifications, no attempt has been made to indicate bias level on the graph in Figure 4 in terms of actual bias current.

Bias level is indicated as a percentage of that which is proper for standard tape; the standard tape value being 100%. The percentage value relationship will hold generally true for all recorders. In a comparison of the bias current vs. output curves, note that the output in db is the same for each tape, but notice also the difference in bias level requirements. The high coercivity low noise tape requires additional bias for a given output in comparison to the standard and extra-play tapes which require less bias.

BIAS AND FREQUENCY

As can be seen from the graphs in Figure 4, the recommended peak bias for a given tape type is that point where the 2 curves cross. With standard and extra-play tape as bias is decreased below the recommended peak, the short wavelength output will be increased but the long wavelength response will suffer. If the bias is increased, the long wavelength response will be improved at the expense of the short wavelength. It is interesting to note that the high coercivity coating used in the low noise tape has essentially the same bias requirement for both low (15 mil wavelength) and high (1 mil wavelength) frequencies. This tape, although requiring greater input drive, allows a bias setting which compliments both the high and low frequencies.

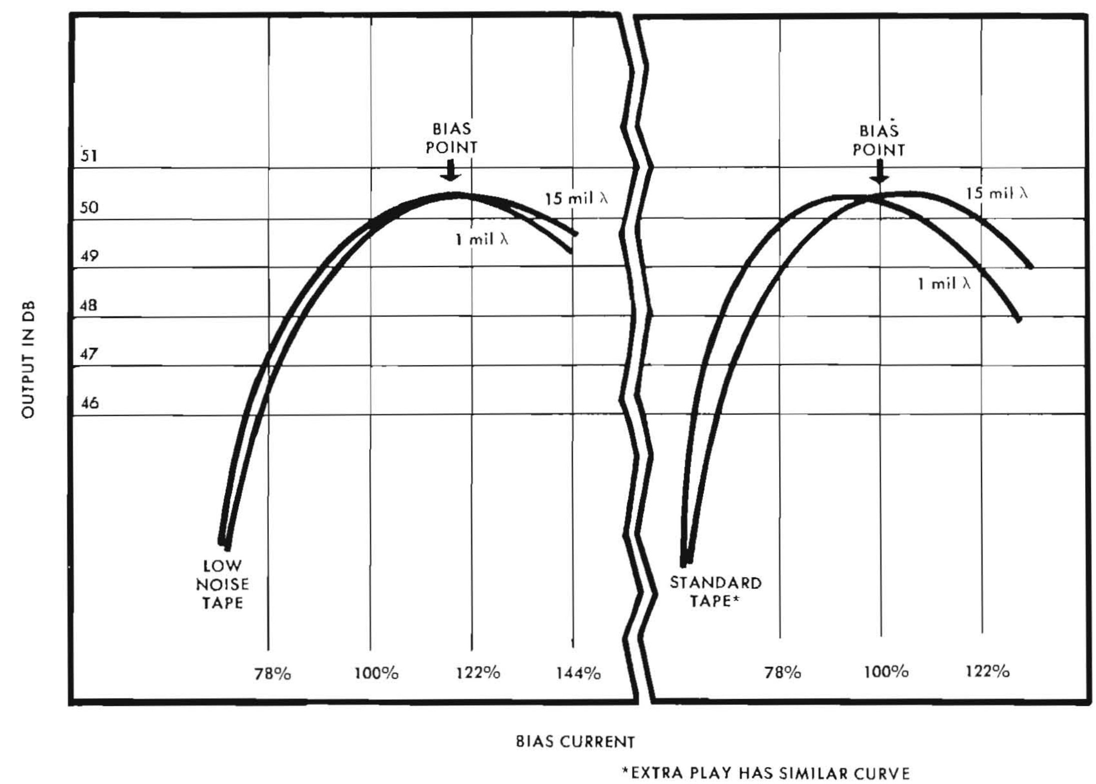


FIGURE 4. BIAS AND WAVELENGTH RESPONSE

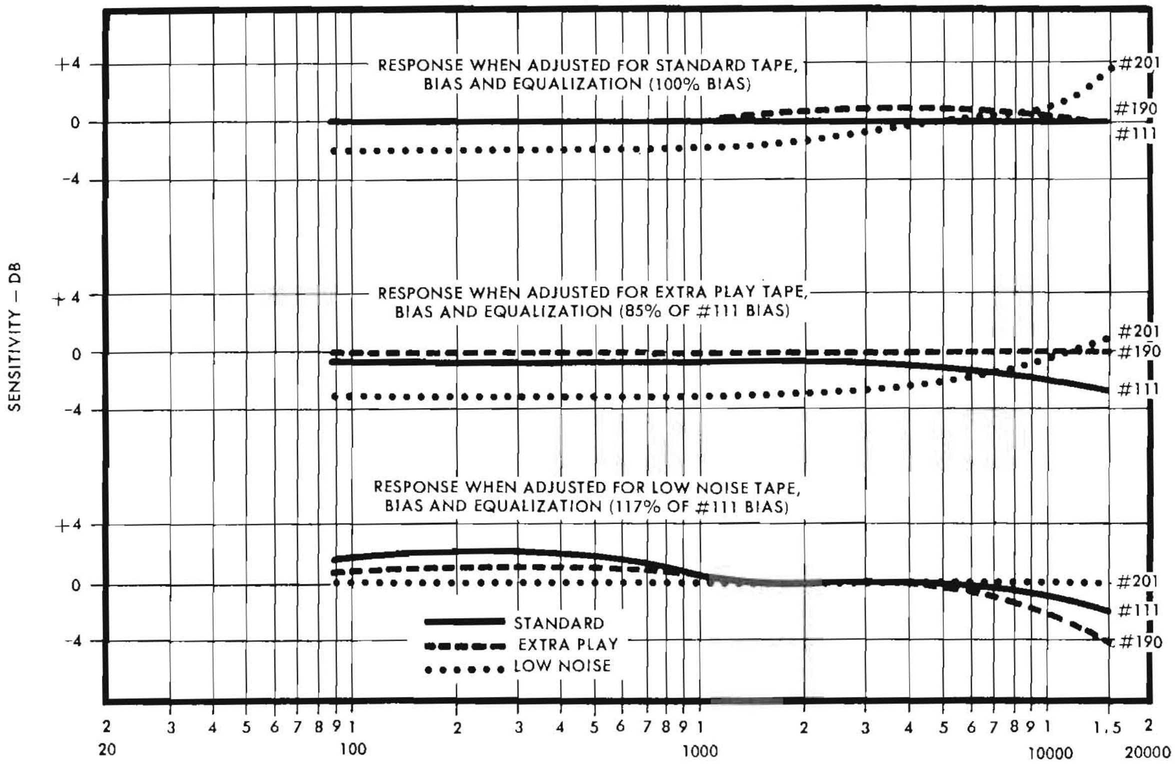


FIGURE 5. NORMALIZED TAPE RESPONSE CURVES

RECORDER OPTIMIZATION

Recalling the discussion of magnetic properties, it was stated that the coercivity measurement represents the flux intensity or magnetic field strength required to record a signal on a section of tape. To maintain a specific output level, a high coercivity tape requires a greater input signal level and, in comparison, the lower coercivity tape requires less drive. Notice, though, that in all cases the bias requirements for a given tape type do not constitute a major change in the recording system. To compensate for the differences in tape sensitivity, the equalization settings of the recorder can be adjusted so the frequency response curve will achieve the desired overall flat response. Figure 5 shows the result of optimizing bias and equalization for each tape type and the effect this has on the other two tapes. To achieve perfect results these can be adjusted, but because the amount of change in record level, bias, and equalization is only minor, the average outputs from the different tapes do not vary widely from each other. The three tapes can be interchanged without any severe decrease in overall performance.

Flat response can be attained, within the limits of the recorder amplifiers, with specific input settings. As shown in Figure 5, the plotted sensitivity range for the different tapes is about 3.5 db. The differences in bias and equalization for flat response for a specific tape will create slight response differences for the other tapes. The response curves exhibited by each tape show that a compromise setting can be used so that all the tapes will produce a similar and relatively flat response curve. The recommended compromise setting for tape interchange is at a bias setting of the standard tape (100%) or just slightly higher. With a bias setting of 105 to 110%, the three tapes will achieve a similar response with less than 1.5 db difference. With this compromise setting, the equalization can remain at a point that was proper for the standard tape.

SUMMARY

The three most popular types of magnetic recording tape do exhibit individual magnetic properties which are a function of the oxide dispersion forming the tape coatings. For maximum performance with a particular tape, the recording system can be adjusted for optimum bias, record level, and equalization. Because the individual differences are not extreme, a compromise setting can be used so the tapes can be interchanged without appreciable loss in performance. By using a recording tape which is properly designed and manufactured, an increase in overall performance can be attained without sacrificing tape-to-tape and tape-to-recording system compatibilities.

If at any time additional information on this topic is desired, it is available by simply writing to:

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No. 1
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POLYESTER AND ACETATE FOR MAGNETIC RECORDING TAPE BACKINGS

Within the magnetic recording industry, only audible range recording tape is available with both polyester and acetate as a backing material. It is interesting to note that the recording tapes used for other applications such as video, instrumentation, and computer rely almost entirely on polyester backing materials. For these applications polyester is the preferred substrate because of two basic properties, stability and strength. These properties are also of definite interest to the audible range recording industry, so this issue of SOUND TALK will compare the performance of both polyester and cellulose acetate film in terms of their use as backing materials. Some of the physical parameters which define the basic properties will also be discussed.

During its extensive life, magnetic recording tape may be subjected to a variety of environmental changes. The temperature and humidity, which are constantly changing, will affect the backing material used in all recording tapes. The tape backing, during these changes, will expand or contract. This change in physical dimension affects its wind-stability and ultimately its overall life expectancy. These finite variations created by environmental changes are reflected in the basic property of stability which, as we will describe, is different for the two backing materials. During the use of recording tape, the stresses and strains which the tape receives will vary. The ability to withstand these forces is determined by the physical strength of the backing material. The two materials being examined exhibit subtle differences that we can observe by various testing techniques.

STABILITY

A basic requirement of a backing material is to maintain its dimensional stability when subjected to changes of temperature and humidity. Differences which do occur and can be measured when comparing the two materials are expansion, cupping, and wind stability.

EXPANSION COEFFICIENTS

The thermal and hygroscopic coefficients of expansion of each material define some of the differences between them. The thermal coefficient of polyester is 2×10^{-5} in/in/°F. The coefficient of acetate is 3×10^{-5} in/in/°F. We must conclude that neither material is detrimentally sensitive to temperature changes. Even though polyester expands only two-thirds as much as acetate, the numbers are so small that the result is rather unimportant.

The significant difference in materials, however, lies in their moisture or hygroscopic coefficients. Polyester expands or contracts at the rate of 6×10^{-6} in/in/%R.H. Acetate on the other hand has a coefficient of 50×10^{-6} in/in/%R.H. Although these, too, are rather small numbers, notice that polyester is 8 times *less* sensitive than acetate to changes in relative humidity. As an example, let's use these expansion or contraction rates to determine how the length of two 7200 foot rolls of tape will change when the RH changes 60%. The thickness and width will also change the same percentage, but this change will be negligible when compared to the absolute change in length. One of the rolls will be 1 mil polyester and the other 1 mil acetate.

From the following computation, notice that a 60% change in Relative Humidity creates a change in length of the polyester tape of about 2½ feet.

Length (Poly.)

$= [6\,(10^{-6})$ unit change/%R.H.$] \times 7200$ ft. $\times 60\%$ R.H.

$= 6\,(7.2)\,(6)\,(10^{-2})$ ft.

$= 2.59$ ft.

Using the same formula, notice that under the same conditions the acetate sample changed over 21½ feet.

Length (Acet.)

$= [50\,(10^{-6})$ unit change/% R.H.] x 7200 ft. x 60% R.H.

$= 0.5\,(7.2)\,(6)$ ft.

$= 21.60$ ft.

At 15 ips, this would amount to a 2 sec. difference, a negligible change, in the running time of the polyester roll. The acetate, however, changes about 17 seconds.

CUPPING

The moisture sensitivity of acetate also shows up in another manner. A short, single strand of acetate tape, if exposed to a wide range of Relative Humidity, will not remain flat through this range. The tape will have a tendency to curl across its width. Observing a cross-sectional view of the tape end, as in Figure 1, you would note the amount of cupping is measured in degrees of arc (flat tape is taken as zero). Samples tested at 15, 50, and 85% R.H. showed the amount of cupping is related to the relative humidity level. A typical 1½ mil acetate tape measures 4° at 15%, 8° at 50%, and 16° at 85%. Thus the acetate may cup badly at high humidities while remaining relatively flat below 50%. The acetate's change in cupping throughout this 70% R.H. range was 12° while the polyester changes less than 1°. The reason for acetate's change is its absorption and loss of moisture that causes a differential in expansion and contraction when compared to the magnetic layer.

Another type of cupping apparatus measures the height of the arc. This distance can be ascertained by viewing the edge of the sample through a calibrated microscope eyepiece. Regardless of the measurement, cupping is considered detrimental because it disrupts head to tape contact.

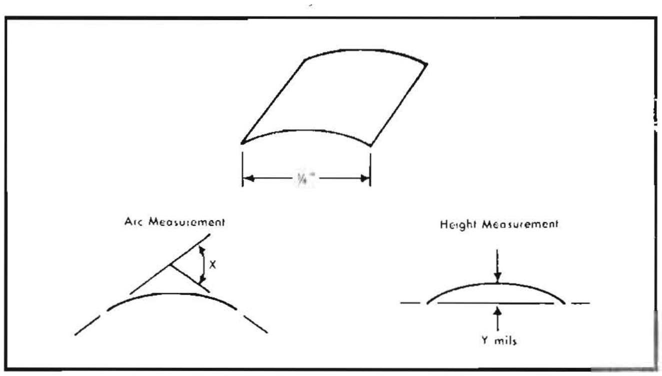

FIGURE 1. CUPPING

WIND STABILITY

Another important humidity effect is apparent in the tightness of a roll of tape. An acetate roll wound at moderate tensions with constant torque at 50% R.H. and normal room temperature will become very loose when the R.H. is raised to 95%. At 5% R.H. and normal room temperature the same roll becomes very tight. For a duplicator with a 7200 foot bulk roll, a loose wind makes the roll quite difficult to handle because the roll may fall apart. A tight wind may cause the roll to become dished, making it difficult to handle on the duplicating slaves. The tight wind could cause stresses within the roll that may result in permanent physical distortion.

A roll of polyester will not exhibit these changes after being submitted to the same range of conditions. Seasonal changes may create either loose and tight winds of acetate bulkpack rolls because of the day to day changes in relative humidity. Some users may consider environmentally regulated storage areas for acetate tape. The wind stability of polyester, with respect to changes in relative humidity, is much more predictable than acetate.

STRENGTH

Another important property of magnetic recording tape is its ability to withstand stresses and strains which occur during use. The simplest method of a comparison between the two backing materials is to subject them both to a series of tests which determine tensile strength during tension and their shock tensile strength to withstand a sudden application of stress. Still another strength parameter is the ability of the backing to withstand minor damage and aging and still remain in usable condition.

TENSILE STRENGTH

The tensile strength test is accomplished by attaching a tape strand to two fixtures or jaws, one is stationary and one is capable of being moved at a constant speed (figure 2). The tension imposed on the stationary jaw is measured by a force transducer as the movable jaw pulls on the sample. The output of the transducer provides an electrical signal which deflects the pen of a chart recorder in proportion to the force. The chart paper is moved in proportion to the distance the movable jaw travels, thus generating a force versus elongation curve. The curve shows the backing's strength when subjected to a constant rate of elongation.

Figure 3 is a graph of typical samples of 1½ mil polyester and acetate tested on the apparatus at 50% R.H. Even though this curve represents 50% R.H. the polyester would be essentially the same at any humidity because polyester's strength is virtually unaffected by the presence or absence of moisture. During this test a typical polyester sample elongates 100%. This is a deceiving figure, however, because magnetic recording tape is useless once it has stretched beyond 5%. The knee of the curve appears at approximately this 5% point. Below 5%, the backing's elasticity allows it to return to essentially the same length and shape as when it was under no tension. Beyond this knee at 5%, the film is permanently distorted. After the 5% point, the tape continues to lengthen without additional force for a short time,

then more force is required to reach the breaking point. Finally, breakage occurs at approximately 100%. This percentage can vary from about 90 to 150%, but 100% is typical.

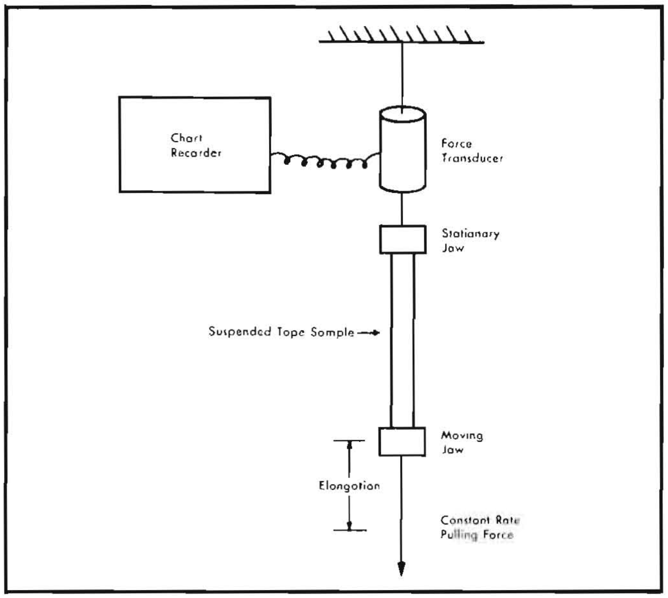

FIGURE 2. TENSILE STRENGTH TESTING APPARATUS DIAGRAM

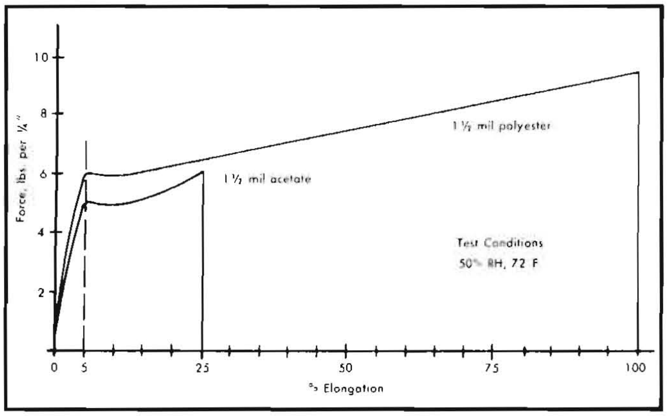

FIGURE 3. TENSILE PROPERTIES OF 1½ MIL BACKING

During the comparison test of a 1½ mil acetate tape sample, notice that the acetate also stretches, but not nearly as much as polyester. Breakage occurs after 25% elongation. Also, this breakage figure varies considerably depending on both the edge quality of the tape and the relative humidity. The permanent deformation point (yield point), is again approximately 5%; the same as polyester. But about 15 to 20% less force is required to permanently distort acetate. For 1½ mil polyester bases, the 5% point is reached at about 6 lbs. per ¼ inch. For 1½ mil acetate, it is only about 5 lbs. per ¼ inch. Notice that under the conditions of test (normal room temperature and 50% R.H.), acetate and polyester both stretch, but the acetate sample is permanently deformed at 20% lower force.

Figure 4 shows how 1 mil polyester and acetate tapes compare. The same general relationship exists between the two different 1 mil bases as with the 1½ mil bases as previously illustrated. The major difference lies in the forces required to stretch and break the tapes. Since the base materials will withstand an established constant force per cross-sectional area, the thinner caliper tapes, having reduced cross-sectional areas, will stretch and break at lower forces.

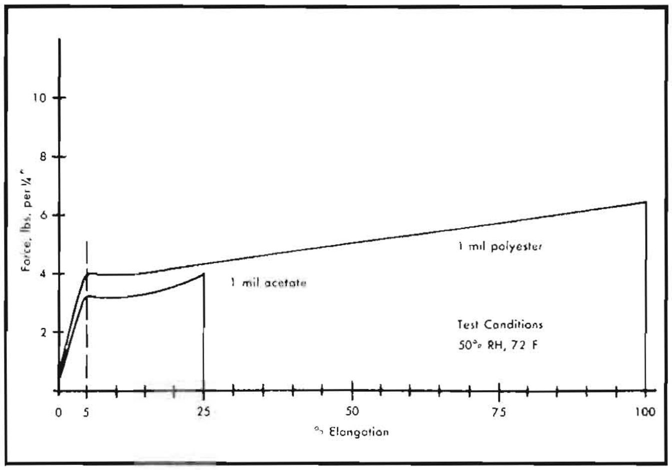

FIGURE 4. TENSILE PROPERTIES 1 MIL BACKING

The effect of temperature on the 5% yield point of 1½ mil acetate and polyester is shown in Figure 5. At low temperatures, both tapes require more force to reach permanent deformation than they do at room temperature. The higher the temperature, the lower the required force. Notice the two lines are parallel, indicating that both materials are affected to about the same degree.

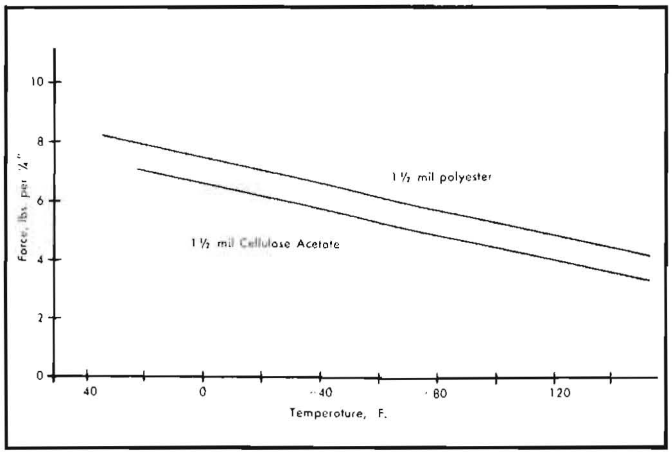

FIGURE 5. TEMPERATURE EFFECTS ON 5% ELONGATION POINT

Since acetate is hygroscopic (absorbs moisture), it has different tensile properties at different humidities. As an example, Figure 6 illustrates the tensile properties of 1½ mil acetate at three different humidities. The tests were made at 15%, 50%, and 80% R.H. with a constant 72°F. temperature. At 85% R.H., acetate stretches much easier and elongates much further than it does at 50% R.H. At 15% R.H., acetate becomes more brittle and will break sooner although it requires a slightly higher force to reach permanent deformation. At high humidities the acetate absorbs moisture which "plasticizes" the backing, allowing it to become more flexible; and, therefore, it is more subject to stretching.

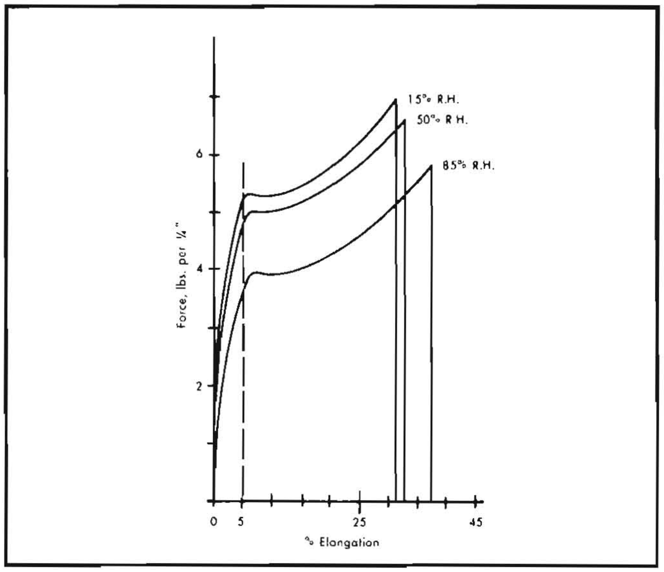

FIGURE 6. ACETATE TENSILE PROPERTIES AT DIFFERENT RELATIVE HUMIDITIES

SHOCK TENSILE STRENGTH

Shock tensile is a test that evaluates how tapes will react to sudden stresses which often can be the cause of breakage. A special instrument is used to apply the forces required during the test. Figure 7 is a simplified drawing of the stress application which corresponds to the Military Specification W-T-0070 testing methods. A weight (or pendulum), attached to a radial arm, is raised a number of degrees and allowed to fall and strike a tape sample. The weight, angle, and radius are determined so that the tape sample at the bottom of the arc is struck with 0.59 ft.-lbs. of energy.

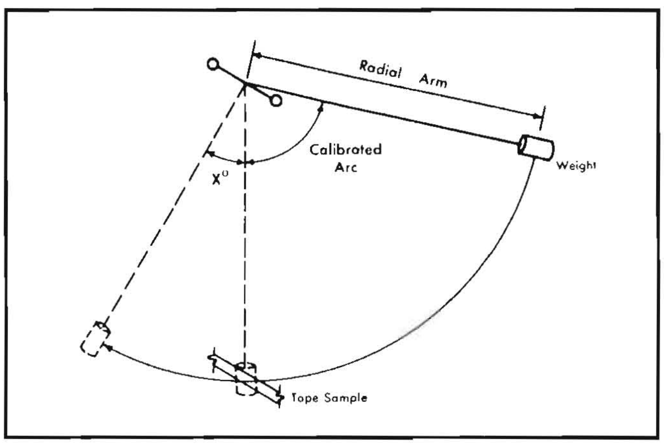

FIGURE 7. SHOCK TENSILE TEST APPARATUS DIAGRAM

The comparison of tapes tested on this apparatus is done by measuring the distance the weight travels after breaking the tape sample (angle X°). If the sample breaks without absorbing any energy, neglecting the frictional losses in the apparatus, the weight will swing to the same height (or angle) as that of its initial position. The difference in the angles, before and after striking the tape, allowing for frictional losses, yields a calculable amount of energy that is absorbed by the tape before it breaks.

The average energy absorption figures for acetate are 0.43 ft.-lbs. for 1½ mil thickness and 0.30 ft.-lbs. for 1 mil. As previously mentioned, because of plasticizing, these figures are extremely dependent upon the Relative Humidity. At lower humidities acetate will absorb less energy and at higher humidities it absorbs more. Depending on ambient conditions, the tape will tend to either plasticize or embrittle. The more moisture, the more plasticized it becomes and the more it stretches before breaking. The stretching action of the tape absorbs the energy of the falling pendulum. At 95% R.H., both 1 mil and 1½ mil acetate material will stretch enough to absorb 100% of the pendulum force and will not break.

During this test comparison, the polyester material of both 1½ mil and 1 mil thickness absorbed the entire pendulum force without breaking, regardless of the relative humidity.

"WEAK" EDGES

A "weak edge" can occur if a tape has been poorly slit during manufacture or damaged in handling. The edge is apparently minutely broken or nicked, and, therefore, has a weak point. To evaluate the effect of the damage to the strength of tape, we took a known good sample roll of 1½ mil acetate. Preliminary tests were performed to assure that it would absorb a minimum of 0.43 ft.-lbs. and stretch normally before breaking. The tapes' edge was then deliberately damaged with a 5 mil nick, using a sharp razor blade and a microscope with a calibrated eyepiece. The edge-nicked samples were then tested. The damaged tape absorbed only 0.07 ft.-lbs. of energy before breaking. No stretching was observed, and the break occurred where the edge nick had been placed. With 5 mils of edge damage, the tape absorbed less than 20% of the energy that it would have if it had good edges. Repeating the same experiment with 1½ mil polyester samples, it was found that the damaged samples did *not* break.

To additionally verify the effect of minor edge damage, static tensile tests were made on samples of the same acetate and polyester rolls. The polyester samples exceeded the 5% permanent deformation point. The acetate samples broke after they elongated about 3%.

Edge damage may be the result of substandard slitting, as occasionally is found in poor quality recording tape. Weak edges also can be the result of improper transport guiding, causing the tape to scrape a reel flange. Damage can also be caused by the bending over of a slightly exposed tape edge in a scattered wind, or by rough handling during thread-up and editing. In all probability, the main cause of acetate breakage is attributable to damaged edges — the direct result of improper handling.

AGING

Cellulose acetate film, as used in magnetic recording tape, contains a plasticizer which is necessary to provide

the required flexibility at all relative humidities. It was discovered that old acetate tapes become brittle because of the gradual loss of the moisture and plasticizer over many years time. In an attempt to verify this effect, shock tensile tests were made on artificially aged rolls of tape. The rolls were aged by placing them in a 150°F. oven for 1,000 hours, which, in the chemical industry, is known to be the equivalent of about 2 to 3 years of normal aging. In a comparison between these "aged" rolls and "un-aged" control rolls from the same lot, it was discovered that the strength of the aged rolls was almost ⅓ *less* than that of the un-aged rolls. This verifies previous theories about aging and the loss of plasticizer, causing the acetate to become more brittle. It was found that moisture can be returned to the tape but that the acetate film would never be as flexible or as strong as it was originally. Since polyester does not contain a plasticizer, it does not exhibit this "aging" phenomenon.

CONCLUSION

Because of the greater stability and strength, polyester film is the preferred type of backing for many applications. Although acetate type backings are considered by some as preferable for editing purposes, the polyester must be considered better for operational reasons. For original mastering and duplicating masters, it is important that a recorded tape remain useable in spite of relatively rough handling. Physical distortion caused by changes in humidity that could be encountered during storage cannot be tolerated in conditions which require precise playback. In duplication, it is important that breakage does not occur either during start-up or during operation. Generally speaking, polyester backing materials offer greater reliability and a larger safety factor against problems that can be both time consuming and costly.

If at any time additional information on this topic is desired, it is available by simply writing to:

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Sound Talk®

A Technical Service to the Industry from the makers of Scotch Magnetic Tape

Volume II
No. 2
1969

SPLICING TAPES AND THEIR PROPER APPLICATION

An ideal splice is one that, when properly made, will remain intact for an indefinite period of time. Its mechanical strength is the first consideration, but there are other areas that may be counted just as important. There must be an absolute minimum of "adhesive escape" around the edge of the pressure sensitive tape used to make the splice, and the splice itself must not cause an audible disturbance on playback. With these three basic considerations in mind, let's investigate the factors and precautions that become part of the design of a splicing tape by the manufacturer and the fundamental rules and possible pitfalls with which the operator must be concerned.

DESIGN REQUIREMENTS

When designing *any* pressure sensitive tape, the two obvious components are the backing and the adhesive coating. In the development of a tape suitable for splicing magnetic recordings, both of these components were chosen with great care.

The backing had to be tough and durable while being as thin as possible. For this reason, paper was not suitable; and plastic was chosen. Both acetate and polyester are currently being used.

Developing an adhesive coating suitable for splicing tape was even more involved. Here, three basic qualities must be carefully evaluated. These are known as (1) shear adhesion, (2) peel back or ASTM adhesion, and (3) thumb appeal.

Shear adhesion can be defined as the adhesive's resistance to being parted from the surface to which it is adhered when pulled in what is commonly called the shear direction. Figure 1 demonstrates this by showing a piece of splicing tape being tested for its shear strength.

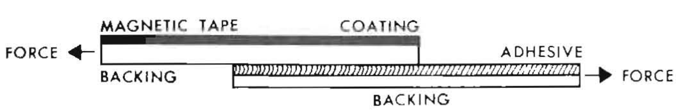

FIGURE 1. SHEAR ADHESION (CREEP)

Peel back or ASTM adhesion is, as its name implies, a measure of the adhesive's resistance to being peeled away from the surface to which it is adhered. Figure 2 graphically demonstrates how this test is performed.

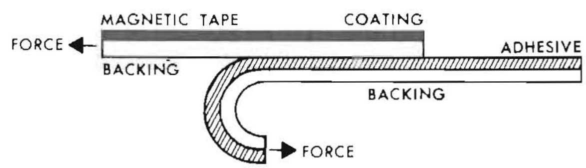

FIGURE 2. ASTM ADHESION (PEEL BACK)

The next property is "thumb appeal" or "quick stick." It is the quality of the adhesive to actually feel sticky. Oddly enough, it is not a particularly important quality as far as the strength of the bond is concerned, but it is a quality that is readily noticeable to the user. There seems to be an "old wives' tale" that has led some users to believe that "the stickier it feels, the better it will hold." This is not necessarily true when talking about splicing magnetic recording tape.

If the thumb appeal is high, the peel back adhesion might be improved to some small degree, but this advantage must be paid for in two ways, neither of which can be tolerated. First of all, with a sticky adhesive the probability of it leaking out from around the bond is greatly increased. This "ooze," as it is called, can be disastrous if it is permitted to exist in splicing tape. The adhesive oozing from under the splicing tape will tend to bond one layer of recording tape to the next layer in the roll. The result, when attempting to re-use the recording tape, would be possible removal of the oxide coating or complete blocking at that point in the reel. Secondly, with an increased "thumb appeal," the shear strength of the splice is reduced. This is evidenced by a degree of parting of the once tightly butted ends of the recording tape and referred to as "creep." Not only will creep manifest itself as an absence of program mate-

rial or a dropout; but now with the parted joint in the recording tape, the exposed portion of adhesive causes the additional problems that we cited above when we discussed ooze. This, then, is why a properly designed splicing tape does not feel very sticky.

SIZE CONSIDERATIONS

Having defined some of the terms, we are now ready to examine the splice itself. There are several variations in splice geometry from which one can select the combination best suited to the conditions of use. These include the size of the spliced area and the angle at which the tape ends meet each other.

Initially, it would be well to discuss the length of a splice and the effect it will have on strength. The length of a splice is dictated, basically, by the amount of curvature it will have to sustain in its path from reel to reel. (Figure 3A).

When the recording tape passes around the sharply curved surface of a guide as pictured in Figure 3B, there is a tendency for the leading edge of the splicing tape to continue in its original direction. It is, in effect, attempting to peel itself away from the recording tape. We are now back to one of our three previously discussed adhesive parameters, that of peel back or ASTM adhesion. With a given splicing tape, the amount of peel back is decided in manufacture and, of course, is constant. The length of the splice has no effect on the tendency to peel but is important for another reason.

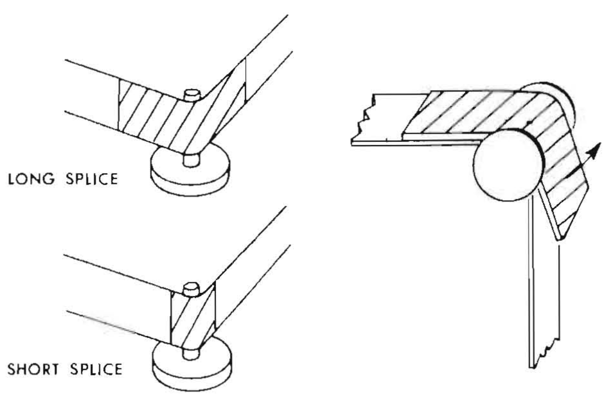

FIGURE 3A & 3B. SPLICE LENGTH AND BEND RADIUS

As shown in Figure 4, a short splice may tend to loosen when subjected to a tight bend because the area of peel may extend far enough into the tape's bond to completely free one end of the recording tape.

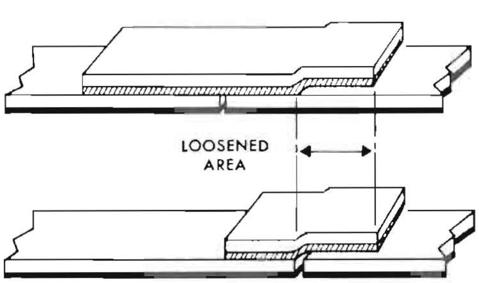

FIGURE 4. ENLARGED VIEW OF LOOSENED SPLICE

A longer splice will exhibit the same amount of peel but the area of peel in this case does not extend all the way to the recording tape junction. The bond at the junction is essentially undisturbed, and the splice passes the guide successfully. Of course, once the spliced area is wound on the take-up reel, the leading edge of the splicing tape that tended to peel is resecured to the recording tape by the pressure of the succeeding wraps as they are wound onto the take-up reel.

While it is impossible to assign a set of definite numerical values, generally speaking, use a long length splice if small radius bends or turns are expected.

As mentioned earlier, the tendency to creep is dependent on the shear strength of the splicing tape adhesive. The force that opposes this shear strength is, of course, the amount of tension the tape encounters on the transport and while wound on the reel during storage. The amount of shear strength is constant for a given splicing tape. If subjected to a constant tension, the important variable affecting creep is then the area of the bond. The larger the bonded area, the better will be the creep resistance.

A splicing tape with poor adhesive shear strength could be used if the area of the splice were greatly increased. Since the width dimension is limited by the recording tape, the area could only be increased by additional length. We could imagine a spliced bond 2 or 3 feet long, but that, of course, would be almost impossible to execute mechanically. Since the program material may drop in level as much as 4 db in the area of the bond because of the change in flexibility, the shorter the splice, the less disturbance there will be during playback. It is, therefore, important that the splicing tape chosen for use has high adhesive shear strength so the spliced length can be kept short.

SPLICING TAPE WIDTH

Much has been said and written about using splicing tape that is the same width as the recording tape and that which is somewhat narrower. It would be well to examine some of the variables and draw some conclusions.

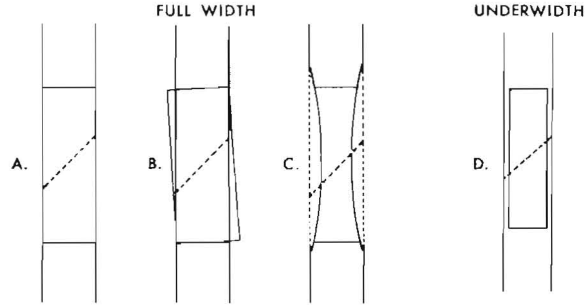

FIGURE 5A-B-C-D. SPLICING WIDTHS

When using the full width splicing method, such as shown in Figure 5A, care must be taken to trim the splicing tape exactly at the edges of the recording tape. If the splicing tape is poorly trimmed (Figure 5B), the overhanging adhesive coated splicing tape is apt to adhere to an adjacent layer on the reel, causing a problem similar to that encountered with ooze. Even though some splicing jigs are designed to cut an arc into each side

of the splice, as shown in Figure 5C, to insure against the possibility of overhang, this does not completely eliminate the chances of some adhesive oozing out of the edges.

Figure 5D illustrates a splicing tape somewhat narrower than the tape to be spliced. This technique offers a number of advantages with no apparent disadvantages. Since the splicing tape does not extend to the edges of the recording tape, overlap — as mentioned earlier — is no longer a problem. A simple splicing jig can be used because there is no need to undercut the spliced area in an hour-glass configuration. Notice that the use of a somewhat narrower splicing tape does not appreciably sacrifice the overall bonding area when compared to full width splicing tape that has been undercut.

RECOMMENDED SPLICING METHOD

In conclusion, let's examine the preparation of recording tape prior to the actual application of the splicing tape.

The most desirable method is to cut the recording tape to be spliced at an angle of 45° to 60°, measured with respect to the tape edge. As the angle increases above 60° towards a perpendicular cut, the amount of electrical disturbance is increased because the head sees the discontinuity at the junction as an abrupt change.

The shallower the angle, the less will be the amount of disturbance. But, as the angle is decreased below 45°, the pointed corners of the recording tape become vulnerable to being peeled back or debonded.

Regardless of the type of splice used, the first and possibly the most important consideration is cleanliness. The hands should be free of all dirt, dust, and oils as one fingerprint on the oxide can drop the output several db. Also, contamination of the recording tape backing or the adhesive of the splicing tape will usually reduce the strength of the bond between the two and can result in premature failure. After carefully placing the recording tape in a splicing jig, it should be cut as carefully as possible, using a sharp, demagnetized razor blade. When handling pressure sensitive splicing tape, care should be taken not to handle the adhesive more than is necessary. After carefully laying the splicing tape down so as not to disturb the alignment of the splice, the finger should be rubbed over the tape to promote intimate contact between the two pieces. Then to remove the air pockets, using the flat of the fingernail is recommended. The selection of the proper splicing tape and the use of correct splicing techniques will assure you of a clean, long lasting splice with no audible discontinuities.

If at any time additional information on this topic is desired, it is available by simply writing to:

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Sound Talk®

A Technical Service to the Industry from the makers of Scotch Magnetic Tape

Volume III
No. 1
1970

THE HANDLING & STORAGE OF MAGNETIC RECORDING TAPE

Much of the world's entertainment and historical events are being preserved on magnetic recording tape. Professional recording studios and tape duplicators, historians and educators, audiophiles and home recordists are all concerned about the permanence and recoverability of the information that is invisibly stored on a thin plastic ribbon.

The preservation of both operating and historical recordings is the primary concern. But, another factor of real importance is the prevention of damage to the recording tape, not just so the information will be safeguarded but so that the maximum use may be obtained from every reel of tape. Both of these factors are economic in nature.

If stored information is unrecoverable because of either lack of safeguards by operating personnel or major catastrophe during storage, the result could be anything from temporary inconvenience to a complete loss of a recording library. If reels of tape are failing before their normal life expectancy, operating expense is increased. Of course, this, too, is undesirable.

This issue of SOUND TALK will discuss in depth the considerations and practices that 3M Company considers of greatest importance to the user of magnetic recording tape. If every one of the many suggestions were followed completely, an ideal situation would exist. Since many recording facilities will function adequately with less than the ideal, you may wish to adopt only a portion of the recommendations. Some of the precautions may be considered too time-consuming or too costly for a given application. In short, it can be said that the overall performance of magnetic recording is directly proportional to the care that is exercised in the two important topic areas: HANDLING & STORAGE.

THE BASIC FACTS

Modern magnetic tape coatings have the ability to retain the intelligence placed on them during the recording process for an infinite amount of time. The recorded information does not tend to fade or weaken with age. It is essentially permanent and will remain unchanged until actually altered by an external Magnetic Field. This erasing of the tape may be done *intentionally*, so that the tape can be used for another recording, or *accidentally*, by operator error or poor storage procedures. Later in this paper the matter of accidental erasure will be more fully discussed.

Even though the magnetic signal will not deteriorate, the physical properties of the recording medium are susceptible to damage. As a general rule, the problems encountered with recording tape performance are predominantly physical in nature. Therefore, it is important to preserve the tape in a form that will make it physically possible to recover the recorded information when needed. Poor handling habits or faulty procedures can render a tape useless because of physical damage. A great deal can be said about the physical preservation of recording tape; and to make the information more meaningful, each of several topics will be treated separately.

THE RECORDING AREA

Ideally the equipment room of a recording studio or professional recording facility should approach, as closely as possible, a "clean room" environment. By definition, this area is characterized by the absence of normally expected airborne dust and lint. The design of the recording equipment area should be such that reasonable control of temperature and relative humidity can be exercised. Variations of temperature should be held within $\pm 5°$ F. of a pre-selected value and the relative humidity should be kept constant to within $\pm 10\%$. In broad terms, this would be a temperature in the 70's and a relative humidity of about 40%.

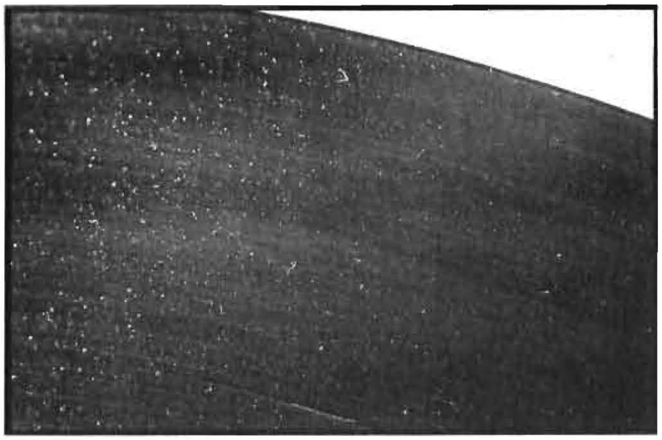

FIGURE 1. ENLARGED VIEW OF DUST CONTAMINATION ON A REEL OF TAPE.

It is doubtful that smoke will contaminate the tape, but ashes can. Therefore, smoking should not be allowed directly over the machines or when handling tape. Food and drink should also be prohibited. Minute food particles can easily be transmitted to the tape and tape decks from the operator's hands. A spilled drink will contaminate not only the tape but also seriously affect a machine's operation.

The integrity of the equipment area should be maintained by periodic cleaning of shelves and floors. When vacuum equipment is used for cleaning, the exhaust from this unit must be located outside the room.

Aside from the direct benefits gained from a well maintained, clean, temperature and humidity controlled environment, the psychological effect upon the employees is of great importance. It is found that operators exercise more care and are more concerned with quality when working in an environment such as just described.

When recording on location or at home, it may be difficult to control the surrounding environmental conditions. Contamination (dust, dirt, debris) can enter the tape transport and cause tape damage. The only positive method of preventing contaminated tape is to eliminate the entry of foreign material into the machine. It is recommended that the recorder (and playback unit) always be covered during storage and as much as possible during operation. Some equipment manufacturers provide, or have available, some type of dust cover which covers the tape drive mechanism and effectively seals out contamination. Many of the protective covers permit the machine to be operated while they are in place and are ideal for use in uncontrolled environment.

TAPE STORAGE

The temperature and humidity of the tape storage area should closely approach that of the work area. The smaller the environmental change experienced by the tape, the better will be its operation and reliability. As a general rule, a temperature between 60° and 80° F. and a relative humidity between 40% and 60% is recommended. If the environmental conditions of the storage area vary widely from the recording area, allow time for the tape to reach temperature and humidity equilibrium before putting it into use.

FIGURE 2. EXCELLENT STORAGE METHOD FOR WIDE WIDTH PROFESSIONAL TAPES.

Recording tape, especially cartridges and cassettes, stored or casually laid on the dashboard or in the glove compartment of an automobile can be damaged by the heat generated by strong sunlight. The molded cases used for some cartridges and cassettes can be permanently distorted if subjected to high temperatures. Both cartridges and cassettes use splices within their tape rolls which can be affected by heat. The splices may separate, and the adhesive may soften and "ooze" from the edges of the splice and stick to adjacent tape layers. The exposure of the splice adhesive will also collect any contamination present in the case, causing additional problems.

Protection from accidental erasure while in the storage area is easily accomplished and is, ironically, of little concern. There are two reasons why this is true. First of all, fields strong enough to cause erasure are just not normally found in an "office or home" atmosphere.

Secondly, if the tape is kept as little as 3 inches away from even a strong magnetic source, this spacing should be sufficient to offer adequate protection. During storage, the tape must be enclosed in a container (original box, plastic case, tape canister) for several reasons. One reason is to provide protection from physical damage. Another reason for using a container is obviously protection of the reel from dust.

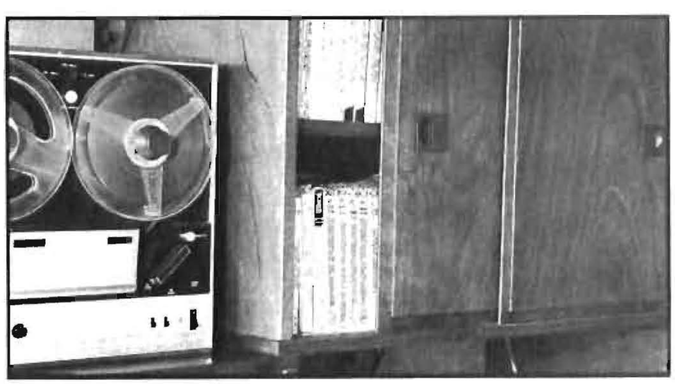

FIGURE 3. TAPE STORAGE AT HOME.

The closed containers should be placed into storage on edge, so that the reel is in an upright position. While they may also be stored individually, lying flat, tape boxes should never be stacked so high that there is a possibility of crushing or distorting the bottom container from the excessive weight of the stack, since this could cause edge damage to the reel of tape in that canister. For long term storage, additional protection from dust and moisture can be gained by sealing the container in a plastic bag. It is generally considered good practice to clean the container before using it so that dust that has accumulated during storage will not contaminate the recorder or tape.

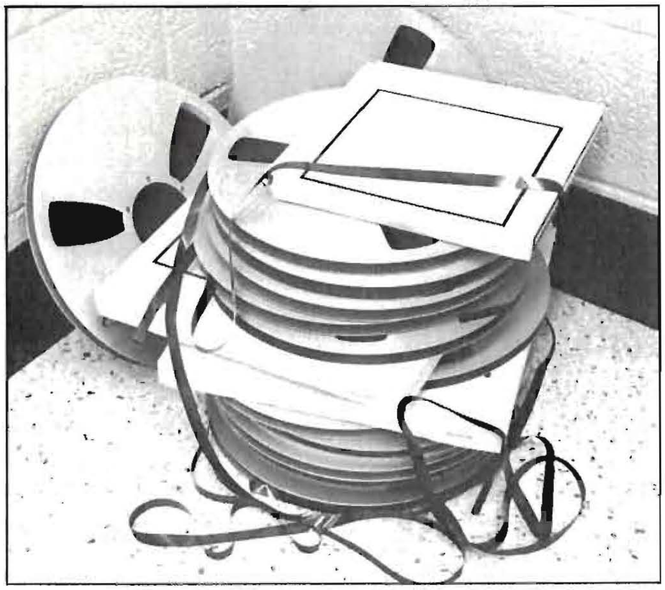

FIGURE 4. OBVIOUSLY THE WRONG WAY TO STORE TAPE.

The care exercised in preparing tapes for storage is every bit as important as the excellence of the storage area. Of primary importance is the way the tape is wound on the reel, since poor winding can result in distortion of the tape's backing.

A wind tension that is relatively low is recommended. Three to four ounces per ¼ inch of tape width is sufficient to render a firm, stable wind on an NAB hub or reel configuration. This tension, while great enough, does not result in high pressures within the roll that could permanently distort the backing. Backing distortion, caused by extreme pressures within the tape pack, may result if a roll of tape wound too tightly is subjected to an increase in temperature while in storage.

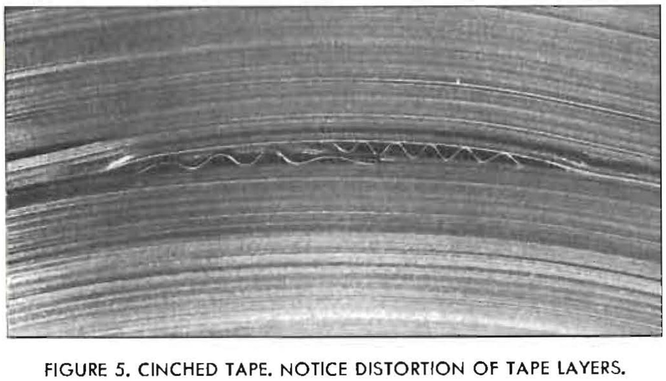

FIGURE 5. CINCHED TAPE. NOTICE DISTORTION OF TAPE LAYERS.

Just as there is the possibility of problems if the tape tension is too great, too low a wind tension can cause difficulty too. If the wind is too loose, slippage can occur between the tape layers on the reel. This "cinching," as it is called, can distort the tape by causing a series of creases or folds in the area that has slipped. When the roll is unwound, the surface will be wrinkled. When an attempt is made to use the tape again, the wrinkles and creases will disrupt the necessary intimate contact between the tape and the head. Because the tape is repeatedly lifted from the head, the result will be a series of signal variations. If the tape is properly rewound immediately after cinching, there is a good possibility that the information may be saved.

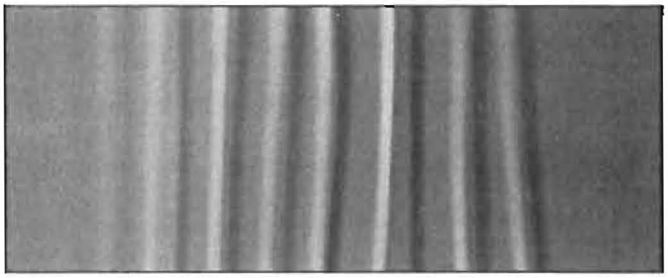

FIGURE 6. TAPE DAMAGE CAUSED BY CINCHING.
THIS STRAND OF TAPE
CLEARLY SHOWS THE WASHBOARD-LIKE WRINKLES.

Some recorders now in use do not have a method of adjusting wind tension; therefore, care must be taken while operating these machines. Sensible operation of "Fast Forward, Rewind and Start" controls can eliminate the sharp stress loading associated with starting and changing tape directions. Tape distortion and "cinching" can be reduced by allowing a minimum slack loop when threading and starting the machine. It is also good practice to allow the spinning tape reels to completely stop before changing tape direction.

Along with proper tension, another important consideration is wind "quality." The successive layers of tape should be placed on the reel so that they form a smooth wind with no individual tape strands exposed. A smooth wind offers the advantage of built-in edge protection.

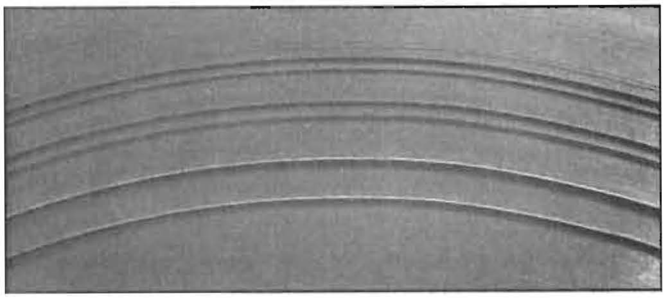

FIGURE 7. SCATTERED WIND. INDIVIDUAL TAPE STRANDS
ARE EXPOSED AND VULNERABLE TO DAMAGE.

A scattered wind will allow individual tape edges to protrude above the others. Since there is no support for these exposed strands, they are vulnerable to damage.

It is sometimes suggested that tapes in storage be rewound at specific intervals, such as every 6 to 12 months, to relieve internal pressures. This would be recommended for tapes of marginal quality or for those with other

than heavy duty binder systems. For modern day tapes with polyester backings and advanced binders, this periodic rewind might not be necessary.

A good practice, however, is to select a random sample from various areas of the library for visual inspection. The reels chosen can be examined for loose winds and dust accumulations. They should be checked for rippled edges and other signs that indicate the presence of physical distortion. If anything is found that indicates a problem may exist, additional samples should be inspected to ascertain what percentage of the library may be affected.

If the above recommendations concerning the storage environment and the actual preparation for storage are followed, no serious problems should be encountered even in long term storage.

WHEN TAPES ARE SHIPPED

It is sometimes desirable to send recorded tapes from one location to another. There are certain precautions that apply to the shipment of recording tapes that should be followed to insure safety in transit.

Logically, the first consideration would be the physical protection of the tape while being transported. The outer shipping container into which the tapes are placed must afford the necessary strength and rigidity to protect the tape or tapes from damage caused by dropping or crushing. While a container that is 100% water-tight would not be necessary, it must nevertheless provide a reasonable degree of water resistance. It should, for example, be capable of protecting the contents from being damaged if, during shipping, it is left on a loading dock in the rain.

While it is good practice to always secure the free end of a reel of tape, it is particularly important when preparing reels for shipping. A short length of pressure sensitive tape is all that is necessary.

While the purely physical shipping precautions are not unique to magnetic tape but are considered good practice in preparing any item of value for transport, there is another consideration that is of prime importance. Since the tape is a carrier of magnetic information, measures must be taken to protect the reels from accidental erasure.

Laboratory conducted tests have determined what would constitute adequate protection from stray magnetic fields of a magnitude which may possibly be encountered in transit. It was found that field strengths within the tape of 50 oersteds or less caused no discernible erasure.

The average bulk degausser, purposely designed to produce a maximum external field that is used to erase tape while still on the reel, produces a field of 1500 oersteds. Sources of magnetic energy to which tape being shipped might be subjected would be motors, generators, transformers, etc. These devices are designed to contain their magnetic fields to accomplish some type of work. With this in mind, it is safe to assume that field strengths of more than 1500 oersteds would not be encountered in ordinary shipping situations.

Because field intensity decreases rapidly with distance from the source, the 50 oersted point (mentioned earlier as not affecting the tape) is reached at a distance of 2.7 inches from a 1500 oersted source. From this it can be seen that the easiest and least costly method of obtaining erasure protection is by insuring a degree of physical spacing from the magnetic source. It is suggested that tape being prepared for shipment be packed with bulk spacing material such as wood or cardboard between the tape boxes and the outer shipping container.

Based on the information in the paragraphs above, 3 inches of bulk spacing should give adequate protection and virtually eliminate any potential for erasure. This magnetically protective spacing can also be justified because of the excellent protection gained against physical damage to the contents.

Tape in transit may be subjected to temperature extremes. Temperatures as low as −40° F. might be encountered in the cargo hold of high flying aircraft. A temperature of 120° F. could be encountered in a motor vehicle in the summer sun. It must again be emphasized that all incoming tape should be allowed to reach environmental equilibrium before being used.

GOOD OPERATING HABITS

The container in which the tape is stored is probably the cleanest area in the recording studio; and, of course, this is the reason that tapes should remain in the box until actually placed on the tape deck and be returned to the container immediately after use. To maintain the cleanliness of the container, it should be closed when the tape has been removed for use.

The hub is the strongest and most stable part of the reel. *Always handle the reel by the hub and not the flanges.* If this single fact is remembered, you will never be guilty of squeezing the reel flanges together when picking up a roll of tape or when handling it.

It has been said that careless handling and poorly adjusted tape decks are the two predominant reasons why tapes fail prematurely. If strict attention is paid to these two areas, immediate benefits will be noted in increased tape life, and the threat of information loss will be substantially reduced.

When handling tapes, use utmost caution to insure that the tape does not become contaminated by fingerprints. Simply stated, fingerprints are nothing more than deposits of body oils and salts. These oils will not attack the oxide-binder system, but they will form excellent "holding-areas" for dust and lint.

Fingerprints on the backing are just as serious as on the coating because dirt deposits will transfer from the backing of one wrap to the coating of the next wrap on the reel. When a reel that has been contaminated in this manner is put into use, the tape deck itself can be affected and will spread this contamination to other clean reels of tape that are used after the dirty reel.

This is one of the reasons for stressing the importance of visually inspecting the tape deck after each roll of tape is run to determine if cleaning is necessary. If the deck becomes contaminated with dust or wear products

from the tape, complete contamination of an entire roll of tape can easily be the result. Contaminants can collect on heads and guides and be dumped along the backing or coating surface of the tape. This contamination will then be wound into the reel under pressure, causing it to adhere firmly to the surface. Each one of these deposits will appear as a dropout or group of dropouts the next time the tape is used.

Tape contamination caused by fingerprints can be reduced by remembering not to touch the tape unnecessarily. Frequent cleaning of the tape deck will reduce the chance of spreading contamination from one reel of tape to others in the library. A cotton swab or lint-free pad moistened with Genesolve-D (an Allied Chemical Trademark) or Freon TF (a DuPont Trademark) or similar cleaner is recommended for cleaning all components along the tape path. If other types of cleaning agents are used, they should be given time to thoroughly dry before loading the tape. This will prevent damage, should the cleaner have any tendency to attack the magnetic tape. Accumulation of tape wear products on the transport can be largely eliminated by using a high reliability tape.

Empty reels should be thoroughly inspected and cleaned before winding tape on them for storage. Reels with hub damage, such as a plastic burr, or with dirty hubs can cause tape distortion exactly as outlined in the preceding paragraphs. Maintaining reel integrity cannot be over emphasized since valuable information can be lost, not because of tape failure but because the tape was distorted by a dirty reel.

One of the most serious and more common forms of tape failure is generally categorized as edge damage. Damaged edges can be caused by the reel, the tape deck or the operator. A broken or badly distorted reel can quickly damage a tape. The effect of a broken or cracked flange is easily noticed since the tape will exhibit a series of nicks or mutilated areas along one edge, and the cause can be easily detected because of the obvious defect in the reel. A bent or distorted reel, however, can also cause damage to one or both edges if the tape is allowed to rub against the flange when being used. A similar type of edge damage will also occur if any of the deck components are misaligned.

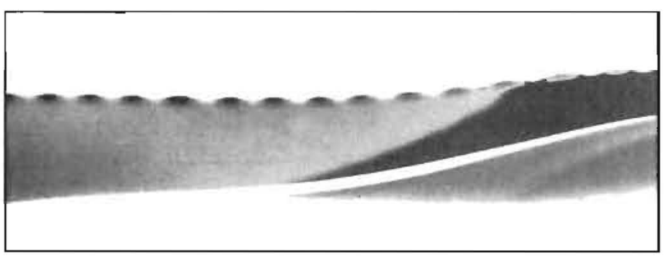

FIGURE 8. SEVERE EDGE DAMAGE.
NOTE THE WAVELIKE WRINKLES ALONG EDGE OF TAPE.

Either of these faults can result in complete failure of a roll of tape. Not only will the edge track be lost, but the debris generated from the edge damage can be redeposited onto the surface of the tape across the entire width. An examination of the edges of a tape that has been damaged in this manner would disclose an accumulation of backing oxide debris.

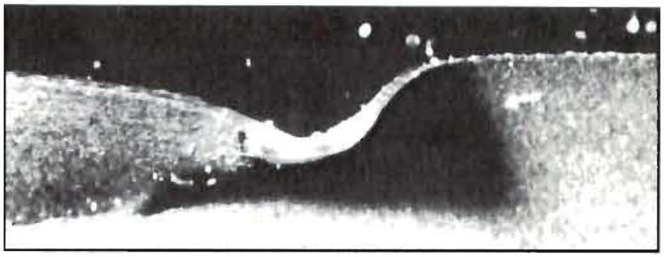

FIGURE 9. MICROSCOPIC VIEW OF A DAMAGED EDGE.
AFFECTED AREA EXTENDS ABOUT 15 MILS INTO TAPE.

While this type of damage is serious, it is sometimes difficult to ascertain its cause or even to notice the effect until the damage is severe. Operators must acquire the habit of physically inspecting the deck in the area of the guides and heads for an excessive build-up of oxide or backing debris. This is generally the first clue that something is wrong. Excessive dropouts on an edge track or loss of high frequencies may also indicate that an alignment or tracking problem exists.

It is also good practice to observe the physical condition of the tape. A sure sign of developing edge damage would be a lip or distortion on the edge being injured. When wound on the reel, the effect of this lip will be cumulative and can stretch the backing. The stretched backing will be rippled and will not conform to the recorder heads the next time the reel is used.

If tape in this condition is properly rewound immediately before being put into storage, it may be possible to salvage the roll. If this is not done, the backing will be permanently stretched and will not recover. This will result in the entire roll having to be discarded.

Operating personnel should use care in handling the reels of tape. It is important that the reel be picked up in a manner that will not cause the flanges to be squeezed together. When the reel is mounted on the recorder, pressure should be applied only to the hub and never to the flange. If the flanges are forced against the tape, this could result in edge damage. This is particularly true if the roll has a scattered wind, since the exposed edges of the misaligned strands can be folded over and creased.

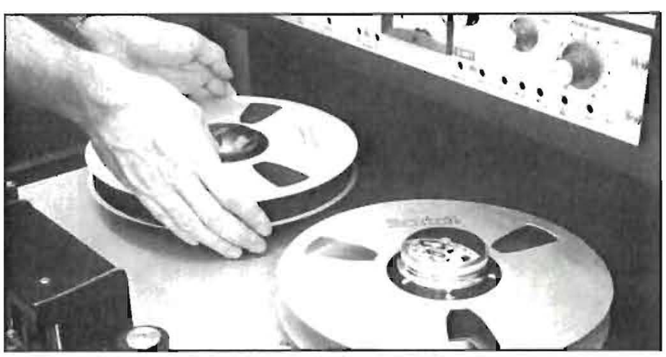

FIGURE 10. PROPER METHOD OF MOUNTING A REEL ON A DECK.
APPLY PRESSURE TO THE HUB AND NOT THE FLANGES.

It is strongly recommended that operators be constantly on the alert for signs of potential trouble. This can best be accomplished by understanding what to look for and by making continuing inspections of both tape and deck a habit.

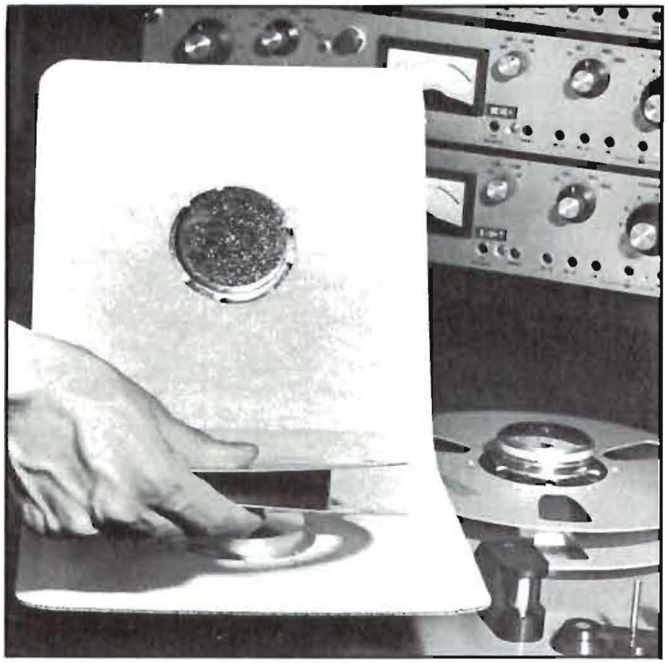

FIGURE 11. IMPROPER HANDLING OF TAPE REEL. SQUEEZING THE FLANGES MAY CREATE SERIOUS TAPE DAMAGE.

MAJOR CATASTROPHE

The discussion, to this point, has been devoted to precautions and suggestions involving the day to day routine use of recording tape. Topics have been explored concerning areas in which the tape is used and stored and recommendations for operator education have been made. The final area of concern, while a remote possibility, is nevertheless of utmost importance because it affects not just a single reel of tape or an isolated recorder but the entire recording operation. This section will be devoted to two forms of major catastrophe: *Fire & Nuclear Radiation.*

For a substance to burn, there must be a breakdown of the organic materials contained in it. The organic materials in Magnetic Tape are the plastic backing and the binder. To burn, these must first vaporize — thus increasing their exposure to the oxygen in the atmosphere — and then rapidly oxidize to form light and heat. An ample supply of oxygen is required to sustain burning.

Since Magnetic Tape contains no "built-in" oxidizer, it cannot burn in the absence of air. Simply stated, its behavior can be closely compared to the way in which a tightly wound roll of paper would burn.

While the "self-ignition" temperature of polyester backed tape is in the neighborhood of 1000° F., temperatures below that point can still cause damage. Polyester film will shrink 1½% at 300° F. and 25% at 325° F. Acetate film, because of its sensitivity to heat, will exhibit greater shrinkage and backing distortion and is more susceptible to heat damage than polyester. If a roll of tape is heated to the approximate temperatures listed below, certain effects would be noted when the roll had cooled.

- 250° F. — Backing distortion.
- 320° F. — Softening of both the backing and binder with some "blocking" or adhesion of adjacent layers.
- 550° F. — Darkening and embrittlement of the backing and binder.
- 1000° F. — Charring of the backing and binder.

When charring occurs, the tape cannot be unwound from the reel, since it will flake when touched. The temperature limitation of present day tapes is a function of the organic components and not a function of the gamma ferric oxide.

Winding and storing magnetic tape properly will lessen the possibility of damage in the event of fire, since tape is a poor conductor of heat. It is sometimes possible to recover information from a tape receiving slight fire damage by carefully rewinding it at minimum tension. The information it contains should be transferred immediately to another reel of undamaged tape.

We recommend the CO_2- type of fire extinguisher for combating burning magnetic tape. CO_2- is clean and this type of extinguisher contains no chemicals that could harm the tape. If water reaches the tape, it will probably not cause complete failure but there may be some evidence of "cupping" or transverse curvature. The amount of "cupping" will depend on the quality of the wind, backing material and the length of time the roll was exposed. If the wind is loose or uneven, the water can more easily reach the oxide surface and the cupping will be more pronounced. The tape should be removed from the water as soon as possible and certainly within 24 hours.

After removal, the rolls should be allowed to dry on the outside at normal room temperature and then be rewound a minimum of two times. This will aid the internal drying and will also help the rolls to return to equilibrium faster. If moisture is allowed to remain within the roll, severe blocking can be the result.

If a temperature increase is also incurred while the tape is water soaked, steam or at least high humidity will be present. This is more likely to cause damage than water alone. A temperature in excess of 130° F. with a relative humidity above 85% may cause layer to layer adhesion as well as some physical distortion.

Once again, the importance of keeping rolls of tape in their containers must be emphasized. The container, if closed properly, will help keep the water spray of a sprinkler system from reaching the tape.

To prevent fire involving magnetic tape, store tape in a non-combustible area and make sure that no combustible materials are stored in the vicinity. An example of a "non-combustible" area would be a room with metal shelves and sheet metal walls. For maximum fire security, store magnetic tape in a fireproof vault that is capable of maintaining a desirable internal temperature and relative humidity for a reasonable length of time.

As a general statement, it can be said that magnetic tape will be unaffected by Nuclear Radiation until the dosage approaches a level 200,000 times greater than that which would cause death in 50% of the exposed humans. Radiation of this level (100 megarep) would tend to increase the layer-to-layer signal transfer or "print-through" by about 4 db but would not prevent information retrieval.

Nuclear Radiation at the above level will also have some physical effect on the tape coating and backing. The backing will show significant embrittlement, and it is expected that the wear life could be reduced by as much as 60%. It is reasoned that whatever Electro-Magnetic Field might result from a nuclear detonation would not be of sufficient intensity to adversely affect the tape; therefore, the threat of signal erasure is virtually non-existent. The effect of Neutron bombardment would no doubt be limited to activation of the iron-oxide in the coating. This would produce a radioactive isotope that itself might become a source of further radiation, but it is theorized that such activation would not produce a change in the overall magnetic properties of the coating.

Radioactive dust or fallout is not capable of producing the dosage necessary to adversely affect magnetic tape. The recommendations made earlier to protect the tape from normal contamination are applicable, as well.

Recent laboratory tests concerning exposure of recorded tapes to x-ray have determined that the recorded signal is not affected by even severe exposure to this source of radiation. The tests involved a commonly used recording tape with several different frequencies recorded on it. The x-ray machine was operating with 200 MA at 110 KV, and a 6 second exposure time at a 36 inch distance was used. Testing and measuring the signal output before and after exposure indicated no signal loss or degradation.

As can be seen from the above discussion, when speaking of major catastrophe, heat and fire damage are considered much more serious than the effects of radiation.

Under proper storage conditions, magnetic tape has the ability to retain intelligence for an indefinite period of time; of greatest importance is the physical preservation of the medium so that adequate head to tape contact can be maintained when the tape is again put into use.

If at any time you have specific questions about this topic, simply write to:

Product Communications
Magnetic Products Division
3M Company
3M Center
St. Paul, Minnesota 55101

Additional copies of this paper are available from your 3M representative, or by writing to the address above.

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AUDIO STANDARDS LISTINGS:

Standards Organizations

Reprinted from Journal of the Audio Engineering Society, June 1970

AUDIO STANDARDS LISTINGS:

Standards Organizations

Note: The editors are pleased to present this new department on standards information affecting the day to day interests of the audio engineer. We are indeed fortunate to have two people whose work has brought them into the standards field. They are H. E. Roys, Chairman and J. G. McKnight, Vice-Chairman respectively of the Standards Committee of the Audio Engineering Society.

INTRODUCTION

As an aid to workers in the audio field, the AES Standards Committee is compiling and will publish lists of existing standards. These will contain industrial, governmental, national, and international standards on the measurement, specification, and standardization of various audio components and systems—general systems and measurements, electroacoustic transducers (microphones, loudspeakers, and headphones), sound recording (disc, tape, and film), etc.

Because new technology is continually developing, all standards are subject to periodic review and users are cautioned to obtain the latest editions from the various standards organizations. These listings will mainly reflect the information given in the latest catalogs at the time they are compiled. Standards known to be under revision are indicated by an asterisk (*).

Lists will be compiled from the catalogs of the following standards organizations.

ANSI: American National Standards Institute, 1430 Broadway, N.Y. 10018, USA (formerly USA Standards Institute, USASI, formerly American Standards Association, Inc., ASA). ANSI does not originate standards itself, but rather provides procedures for establishing national standards called "American National Standards" based on a consensus of those substantially concerned with the scope of the corresponding standards. ANSI has approved a number of audio standards sponsored by EIA, IEEE, and SMPTE. Most foreign and international standards are distributed in the USA by the ANSI. Write ANSI for the current free catalog of ISO, IEC, and American National Standards.

ARD: Arbeitsgemeinschaft der Rundfunkanstalten der Bundesrepublik Deutschland (Association for Radio Stations of the German Federal Republic). The Standards are published for ARD by the Institut für Rundfunktechnik, 2000 Hamburg, Mittelweg 113, West Germany.

BS: Standards published by British Standards Institution (BSI), British Standards House, 2 Park Street, London W.1, England. BSI Sales Branch, Newton House, 101 Pentonville Rd., London N.1, England. These Standards are available in the U.S.A. through ANSI. Write BSI for the following Sectional Lists: SL 10, Acoustics; SL 1, Cinematography; SL 26, Electrical Engineering; and SL 29, Nomenclature.

CCIR: International Radio Consultative Committee, International Telecommunication Union, Place des Nations, Geneva, Switzerland. The texts of CCIR recommendations and reports are published in the documents of the Plenary Assemblies of the International Radio Consultative Committee, every three years. The volume on Broadcasting and Television (Study Group X and others) sells to non-members of CCIR for approximately $6 including packing and postage, and may be ordered directly from the ITU at Geneva. (Not available from ANSI).

DIN: Standards published by Deutscher Normenausschus (DNA) (German Standards Committee). This organization formulates the Deutsche Industrie Normen (German Industrial Standards, DIN) which are widely used in Europe. Although the titles will be given here in English, the original standards are, of course, all in German. Some of the Standards are also available in English translations, sometimes very literal, indicated by

"E/DIN." These standards are sold by Beuth-Vertrieb GmbH, 1 Berlin 30, Burggrafenstrasse 4-7, West Germany. Standards in German, and the "E/DIN" translation, are available in the U.S.A. from ANSI. Some of the standards are available in unofficial translations in finished form, indicated "E/U-f," and some in very rough draft form, "E/U-d," from J. G. McKnight, Ampex Corp., Mail Stop 26-01, 401 Broadway, Redwood City, Calif., 94063, USA. Write Beuth-Vertrieb GmbH for the "DIN Normen-verzeichnis für die heimstudio-, rundfunk-, magnetton-, verstärker-, und phono-Technik, einschliesslich elektroakustischer Wandler und Messtechnik" ("DIN Standards List for 'high fidelity', radio, magnetic recording, amplifier, and phonograph engineering, including electroacoustic transducers and measurement techniques") (in German).

EIA: Electronic Industries Association, Engineering Department, 2001 Eye Street, N.W., Washington, D.C. 20006, USA. Some EIA standards have been approved as ANSI standards. Write EIA for the current free catalog of standards.

IBTO: International Broadcasting and Television Organization, (OIRT in French), Liebknechtova 15, Prague, 5 Czechoslovakia. An international organization of several East European, Asian and African nations, and Cuba.

IEC: International Electrotechnical Commission, 1, rue de Varembé, Geneva, Switzerland. Standards listed in the ANSI catalog and available in the USA through ANSI.

IEEE: Institute of Electrical and Electronics Engineers, Inc., 345 East 47th St., New York, N.Y. 10017, USA (formerly AIEE and IRE). These Standards are available from the IEEE, Order Department. Write IEEE for the current free catalog. Some IEEE standards have been approved as ANSI standards.

ISO: International Organization for Standardization, 1, rue de Varembé, Geneva, Switzerland. Standards listed in the ANSI catalog and available in the USA through ANSI.

JIS: Standards published by the Japanese Standards Association (JSA), 1-24 Akasaka 4, Minato-Ku, Tokyo, Japan. The Standards are available in the U.S.A. through ANSI.

MRIA: Magnetic Recording Industries Association. Merged with EIA in 1965; no Standards issued.

NAB: National Association of Broadcasters (also called NARTB at one time), Engineering Department, 1771 N. Street, N.W., Washington, D.C. 20036, USA. Standards for use by the USA broadcasting industry. No catalog.

PPI: Philips Phonographic Industries, Baarn, The Netherlands. PPI publishes a widely used company standard on cassette recording.

RIAA: Record Industry Association of America, Inc., One East 57th St., New York, N.Y. 10022, USA. Tape and disc record standards. No catalog.

SMPTE: Society of Motion Picture and Television Engineers, 9 East 41st St., New York, N.Y. 10017, USA. These Standards are published in the Journal of the SMPTE in their draft and finally approved forms. The approved Standards are available from ANSI only. Write SMPTE for the current free index to SMPTE Standards.

USA FED.: United States of America, Federal Specifications. Procurement standards for Federal agencies.

a) Bureau of Ships, Department of the Navy

Standards can be ordered from Naval Ship Engineering Center, Code 6665.2M, Washington, D.C. 20360, USA.

b) General Services Administration

Standards can be ordered from the General Services Administration's regional offices in Boston, New York, Washington (D.C.), Atlanta, Chicago, Kansas City (Mo.), Dallas, Denver, San Francisco, and Auburn (Wash.), USA.

UTE: Union Technique de l'Electricite, 20, rue Hamelin, Paris (16^{e}), France. Available in the USA through ANSI in French only.

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AUDIO STANDARDS LISTINGS:

Magnetic Tape Sound Recording

INTRODUCTION

This list is part of a series of lists of audio standards that is appearing in the AES Journal. The full listing of the standardizing organization names and addresses appears on pages 317 and 318.[1]

Arrangement is by the subject of the standard:

1. General Standards (where one document includes several of the subjects)
2. Glossaries, symbols, etc.
3. Recording and reproducing equipment specifications
4. Measuring and adjusting recording and reproducing equipment (including test tapes)
5. Tape
   5.1 Specifications
   5.2 Testing methods
6. Containers for tape
   6.1 Reels
   6.2 Cartridges
7. Tape Records
8. Miscellaneous

Within a subject, entries are alphabetical by the standardizing organization. EIA Standards which are also ANSI Standards are, nevertheless, listed under EIA.

Prices of foreign standards from ANSI are approximate and should be verified with ANSI before purchase. A dash in the "price" column indicates that the standard is not available for sale from that source.

1. GENERAL STANDARDS

(Including glossaries, recording and reproducing equipment, measurements, tape, containers, and tape records in one standard.)

The following two standards are for recording and reproducing equipment and records for professional program exchange.

	Publisher's Price	ANSI Price
IEC Publication 94 Magnetic Tape Recording and Reproducing Systems: Dimensions and Characteristics. Third edition, 1968.	24 Swiss francs	$9.60
Amendment 1 (Changes which replace the "surface induction" specification of recording characteristics with a "recorded tape flux characteristic") (in preparation.)		
Addition 1 Tape cassettes for domestic use: twin-hub, four-track, mono-stereo compatible (in preparation). For the time being, see Philips Phonographic Industries, "Tape Cassette, Twin-Hub Four-Track Mono/Stereo Compatible for Domestic Use" (4th Revision, Oct. 1968). GPG 670. 4/4. (Published in *J. AES* **16**, 430-435, Oct. 1968).		
BS 1568: 1960 + Amendment PD 5962. Dec. 1966 Magnetic Tape Sound Recording and Reproduction (Dimensional Features).	6s	$2.75

The following two standards are for recording and reproducing equipment and records for use by the USA broadcasting industry.

	Pub. Price	ANSI Price
NAB Standard Magnetic Tape Recording and Reproducing (Reel-to-Reel) (April 1965).	Available on request	—
NAB Standard Cartridge Tape Recording and Reproducing (Oct. 1964).	Available on request	—

2. GLOSSARIES, SYMBOLS, ETC.

(See also Sec. 1, General Standards)

	Pub. Price	ANSI Price
ANSI S1.1-1960* Acoustical Terminology (Sec. 8: Recording and Reproducing).	—	$6.00
ANSI Y32.2-1967 Graphic Symbols for Electrical and Electronics Diagrams	—	$6.00
DIN 40 700: Part 7 Graphical Symbols for Magnetic Heads (Sept. 1957). E/U-f	2.50 DM	$2.65
DIN 45 510 Magnetic sound recording: Terminology; German, English, French (Draft, Feb. 1969)	6.40 DM	$3.60
IEC Publication: 50 (08) International Electrotechnical Vocabulary: Electroacoustics (Sec. 08-25: Recording and Reproduction).	10 Swiss francs	$8.00

[1] Audio Standards Listings: Standards Organizations, *J. Audio Eng. Soc.* **18**, 317 (1970).

* Standards known to be under revision are shown by an asterisk.

3. RECORDING AND REPRODUCING EQUIPMENT SPECIFICATIONS

(See also Sec. 1, General Standards)

	Pub. Price	ANSI Price
DIN 45 500		
Part 4 "High Fidelity" Home Equipment: Magnetic tape recording and reproducing systems (Oct. 1967)	2.50 DM	$2.65
DIN 45 511: Tape Recorders:		
Part 1 Tape recorder for recording on magnetic tape with 6.3 mm (0.25 in.) width, mechanical and electrical specifications (Draft, March 1969) E/U-f and E/DIN of March 1966 issue.	4 DM	$3.00
Part 2 Tape recorder for 3- or 4-track recording on magnetic tape with 12.5 mm (0.5 in.) width, mechanical and electrical specifications (Draft, March 1969)	4 DM	$3.00
Part 3 Tape recorder for 4-track recording on magnetic tape with 25.4 mm (1 in.) width, mechanical and electrical specifications (Draft, March 1969)	4 DM	$3.00
EIA RS-288 (1963) Audio Magnetic Playback Characteristics at 7.5 in/s.	$0.50	—
JIS C5550-1967 Magnetic Tape Recording and Reproducing Equipment (in English).	360 yen	$3.20
USA Fed. Specs. W-R-00168a (GSA-FSS) Recorder-Reproducer, Sound (Magnetic Tape Type) (March 1968)	No charge for single copies	—
USA Fed. Specs. W-R-170a Recorder-Reproducer, Sound (Portable, Battery Operated) (May 1966).	$0.10	—
W-R-170a Interim Amendment—2 (GSA-FSS) Interim Amendment (March 1968).	No charge for single copies	—
USA Fed. Specs. W-R-0001404 (GSA-FSS) Recorder-reproducer, sound (portable, battery operated, cassette type) (August 1968)	No charge for single copies	—

4. MEASURING AND ADJUSTING RECORDING AND REPRODUCING EQUIPMENT (Including Test Tapes)

(See also Sec. 1, General Standards)

	Pub. Price	ANSI Price
ARD Basic Specifications for Magnetic Sound Recording Equipment, and General Directions for their Adjustment (June 1965). German only.	5 DM	—
DIN 45 513 DIN Test Tapes		
Part 1 76 cm/s (30 in/s), 6.3 mm (.25 in) tape width (Apr. 1968). E/DIN	2.50 DM	$2.65
Part 2 38 cm/s (15 in/s), 6.3 mm (.25 in) tape width (Oct. 1967). E/DIN	2.50 DM	$2.65
Part 3 19 cm/s (7.5 in/s), 6.3 mm (.25 in) tape width (Oct. 1966). E/DIN, E/U-f.	2.50 DM	$2.65
Part 4 9.5 cm/s (3.75 in/s), 6.3 mm (.25 in) tape width (Jan. 1968). E/DIN	2.50 DM	$2.65
Part 5 4.75 cm/s (1.88 in/s), 6.3 mm (.25 in) tape width (Mar. 1966). E/DIN—for 1962 issue only.	2.50 DM	$2.65
Part 6 4.75 cm/s (1.88 in/s), 3.8 mm (150 mil) tape width (draft, Mar. 1967).	1.90 DM	$2.55
DIN 45 520* Magnetic Tape Equipment: Method for Measuring the Absolute Magnitude and the Frequency Response of the Remanent Magnetic Flux of Magnetic Recording Tape (Sept. 1957) E/U-f.	2.50 DM	$2.65
DIN 45 521 Magnetic Tape Equipment: Measuring the Crosstalk Ratio of Multi-track Equipment (Oct. 1963).	2.50 DM	$2.65
DIN 45 524 Evaluation of the tape speed of magnetic tape transports (draft, March 1969).	—	—
EIA .... EIA Reproducer Test Tape (Open-reel) for tape speeds of 7.5 in/s (19 cm/s) and 3.75 in/s (9.5 cm/s) (in preparation; now Standards Proposal 1030)	—	—
IBTO Recommendation .... OIRT Reference Tapes for the International Programme Exchange.		—
JIS C5551-1966 Testing Methods for Magnetic Tape Equipment (in English).	360 yen	$3.20
UTE C97-110 Electroacoustics: Magnetic Tape Recorders for Semi-Professional or General Public usage: Characteristics and Methods of Measurement (July 1966).	14 French francs	$4.90

5. TAPE

(See also Sec. 1, General Standards)

5.1 Specifications

	Pub. Price	ANSI Price
DIN 45 500		
Part 9 "High Fidelity" Home Equipment: Magnetic tapes (draft, Sept. 1966).		
DIN 45 512		
Part 1 Magnetic Tapes: Mechanical properties (Aug. 1968)	2.50 DM	$2.65
EIA RS-355 (1968) (ANSI C83.45-1969) Standard Dimensions for Unrecorded Magnetic Sound Recording Tape	$0.60	$0.60
USA Fed. Spec. W-T-0070/1 Tape, Audio Type, Cellulose Acetate Base (Apr. 1963)	No charge	—
USA Fed. Spec. W-T-0070/2 Tape, Audio Type, Polyester Base (Apr. 1963)	No charge	—

5.2 Testing Methods

	Pub. Price	ANSI Price
DIN 45 512		
Part 2 Magnetic tapes: Recording performance characteristics (Draft, Feb. 1969) (Aug. 1968)	3.80 DM	$3.00

	Pub. Price	ANSI Price
DIN 45 519 Measuring Methods for Tapes:		
Part 1 Print-through (Oct. 1955). E/U-d	2.50 DM	$2.65
Part 2 Signal to DC-Noise Ratio (Oct. 1955). E/U-d	2.50 DM	$2.65
DIN 45 522 Test Methods for Magnetic Tapes:		
Part 1 Measurement of the coefficient of friction (Dec. 1968)	2.50 DM	$2.65
Part 2 Measurement of flexibility (Aug. 1968)	2.50 DM	$2.65
Part 3 Measurement of nominal strength (Aug. 1968)	2.50 DM	$2.65
Part 4 Measurement of longitudinal curvature	2.50 DM	$2.65
EIA RS-339 (1967) (ANSI C83.35-1968) Recommended Test Method—Layer-To-Layer Adhesion of Magnetic Tape	$0.60	$0.60
EIA RS-342 (1967) (ANSI C83.36-1968) Recommended Test Method—Magnetic Tape Electrical Resistance Coating	$1.40	$1.40
EIA RS-362 (1969) (ANSI C83.56-1970) Recommended Test Method—Tensile Property of Magnetic Tape	$1.20	$1.20
USA Fed. Spec. W-T-0070 Tapes, Recording, Sound and Instrumentation, Magnetic Oxide Coated, General Specifications for (Apr. 1963).	No charge	—

6. CONTAINERS FOR TAPE

(See also Sec. 1, General Standards)

6.1 Reels

	Pub. Price	ANSI Price
DIN 45 514 Magnetic Tape Equipment: Reels, Cine-Type (Mar. 1961). E/DIN, E/U-f	2.50 DM	$2.65
DIN 45 515 Magnetic Tape Equipment: Hub (Mar. 1955). E/DIN	2.50 DM	$2.65
DIN 45 517 Magnetic Tape Equipment: "Disassemble-able" Reel (Identical to EIA and NAB "Type A" reel.)		
Part 1 Hub, flange, screw, and nut (Oct. 1963).	4.00 DM	$3.00
Part 2 Adaptors (Oct. 1963).	2.50 DM	$2.65
EIA RS-346 (1968) (ANSI C83.38-1968) Type A Hubs and Reels for Magnetic Tape	$0.80	$0.80
EIA RS-347 (1968) (ANSI C83.40-1968) ½ Inch Type B Plastic Reel for Magnetic Tape	$0.80	$0.80
EIA RS-351 (1968) (ANSI C83.39-1968) Type B Plastic Reel for Magnetic Tape	$1.00	$1.00
USA Fed. Spec. W-R-175b Reels and Hubs for Magnetic Recording Tape, General Specification for (May 1967).	$0.05	—
USA Fed. Spec. W-R-175/1b Reels, standard, plastic, and fiberglass, 5/16-inch center hole (May 1967)	$0.05	—

6.2 Cartridges

	Pub. Price	ANSI Price
EIA RS-264 (1962) Magnetic Recording Tape Cartridge Dimensions	$0.50	—
EIA RS-332 (1967) (ANSI C83.45-1969) Dimensional Standards—Endless Loop Magnetic Tape Cartridges, Types 1, 2 and 3.	$1.60	$1.60
EIA ...... Magnetic Tape Cartridge—Co-Planar Type CP-2 (Compact Cassette), Dimensional Standards (in preparation; now Standards Proposal 1055)	—	—

7. TAPE RECORDS

(See also Sec. 1, General Standards)

	Pub. Price	ANSI Price
CCIR Recommendation 261-1 Standards of Sound Recording for the International Exchange of Programs, Single Track Recording on Magnetic Tape (1966). Vol. 5, p. 13-15.	See Introduction	—
CCIR Recommendation 408-1 Standards of Sound Recording for the International Exchange of Programs, Two-Track Stereophonic Recording on Magnetic Tape (1966). Vol. 5, p. 23-24.	See Introduction	—
EIA ...... Endless-loop cartridges with eight-track stereophonic records at 3.75 in/s (in preparation; now Standards Proposal 1065)	—	—
EIA ...... Endless-loop cartridges with four-track stereophonic records at 3.75 in/s (in preparation; now Standards Proposal 1066)	—	—
EIA ...... Compact cassettes with four-track mono/stereo compatible records at 1.88 in/s (in ration: now Standards Proposal 1067)	—	—
EIA ...... Open-reel four-track stereophonic records at 3.75- and 7.5 in/s (in preparation; now Standards Proposal 1068)	—	—
EIA RS-224 (1959) Magnetic Recording Tapes (Rev. of REC 138 and REC 132)	$0.60	—
IBTO Recommendation 24 Magnetic Tape Recording for the International Programme Exchange		
RIAA Bulletin E-5 Standards for Magnetic Tape Records (Feb. 1969).	No charge	—
RIAA ...... Standards for Multitrack Magnetic Tape Duplicating Masters (preliminary draft, May 1967).	—	—

8. MISCELLANEOUS

	Pub. Price	ANSI Price
DIN 45 523 Remote Control by Signals from Magnetic Tape Recorders (Jul. 1968).		
DIN 45 525 Evaluation of the Time Period During Which Batteries May Be Used in Magnetic Tape Recorders (draft, May 1968).		
EIA REC-133 (1949) Magnetic Recorder Combined with Home Radio Receivers (reprinted June 1954).	$0.50	—

AMPEX CORPORATION
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LABORATORY REFERENCE ALIGNMENT / TEST TAPES

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TEST TAPES

PRICE SCHEDULE A497 SUPERSEDES A395

EFFECTIVE JULY 1, 19

ALIGNMENT						
WIDTH (INCH)	SPEED (IN/S)	EQUALIZATION (TIME CONSTANTS)	STANDARD	TRACKS	CATALOG NO.	SUGGESTED USER PRICE
1/4	3.75	90 μs & 3180 μs 120 μs & 3180 μs 200 μs & 3180 μs	NAB EIA* Ampex**	Full Full Full	4690037-01 01-31331-01 01-31334-01	$ 23.95
	7.5	50 μs & 3180 μs 50 μs & 3180 μs 50 μs & 3180 μs 70 μs & ∞	NAB NAB NAB IEC***	Full 2 1 & 3 (of 4) Full	01-31321-01 4690010-01 01-31321-04[1] 4690014-01	
	15	50 μs & 3180 μs 50 μs & 3180 μs 35 μs & ∞	NAB NAB IEC	Full 2 Full	01-31311-01 4690009-01 01-31313-01	
	60	3200 Series Duplicator	Special	Full	6878	44.00
1/2	7.5	50 μs & 3180 μs 70 μs & ∞	NAB IEC	Full Full	01-31321-05 4690015-01	38.50
	15	50 μs & 3180 μs 35 μs & ∞	NAB IEC	Full Full	01-31311-05 01-31313-05	
1[2]	7.5	50 μs & 3180 μs 70 μs & ∞ 70 μs & ∞	NAB IEC IEC	8 Full 8	4690007-01 4690032-01 4690021-01	150.00
		50 μs & 3180 μs (BLM-200) 50 μs & 3180 μs (BLM-200)	NAB NAB	8 8	4690007-02[3] 4690041-01[3]	165.00
	15	50 μs & 3180 μs 50 μs & 3180 μs 35 μs & ∞ 35 μs & ∞	NAB NAB IEC IEC	Full 8 Full 8	4690005-01 4690006-01 4690031-01 4690020-01	150.00
	30	17.5 μs & ∞[5] 17.5 μs & ∞[5]	AES AES	Full 8	4690048-01 4690042-01	175.00
2[2]	7.5	50 μs & 3180 μs 50 μs & 3180 μs 70 μs & ∞ 70 μs & ∞	NAB NAB IEC IEC	Full 16 Full 16	4690025-01 4690022-01 4690036-01 4690034-01	275.00
	15	50 μs & 3180 μs 50 μs & 3180 μs 35 μs & ∞ 35 μs & ∞	NAB NAB IEC IEC	Full 16 Full 16	4690024-01 4690018-01 4690035-01 4690033-01	
	30	17.5 μs & ∞[5] 17.5 μs & ∞[5]	AES AES	Full 16	4690047-01 4690039-01	325.00

FLUTTER						
WIDTH (INCH)	SPEED (IN/S)	FREQUENCY (Hz)	UNWEIGHTED RMS FLUTTER (%)	TRACKS	CATALOG NO.	SUGGESTED USER PRICE
1/4	3.75	3000 3150	≤0.03 ≤0.03	Full Full	01-31336-01 4690013-01	$23.95
	7.5	3000 3150	≤0.03 ≤0.03	Full Full	01-31326-01 4690012-01	
	15	3000 3150	≤0.03 ≤0.03	Full Full	01-31316-01 4690011-01	

LEVEL						
WIDTH (INCH)	SPEED (IN/S)	FREQUENCY (Hz)	LEVEL	TRACKS	CATALOG NO.	SUGGESTED USER PRICE
1/4	7.5 15	700 700	Operating[6] Operating[6]	Full Full	01-31325-01 01-31315-01	$19.50

PROGRAM SEQUENCES

ALIGNMENT			
IN/S	FREQUENCY	REPRODUCER OUTPUT VOLTAGE LEVEL	DURATION
3.75	500 Hz	10 dB below operating level	15 seconds
	7.5 kHz	10 dB below operating level	30 seconds
	5 kHz	10 dB below operating level	10 seconds
	2.5 kHz	10 dB below operating level	10 seconds
	1 kHz	10 dB below operating level	10 seconds
	500 Hz	10 dB below operating level	10 seconds
	250 Hz	10 dB below operating level	10 seconds
	100 Hz	10 dB below operating level	10 seconds
	50 Hz	10 dB below operating level	10 seconds
	500 Hz	Operating level[6]	15 seconds
15 & 30	700 Hz	Operating level[6]	15 seconds
	15 kHz	Operating level	30 seconds
	12 kHz	Operating level	10 seconds
	10 kHz	Operating level	10 seconds
	7.5 kHz	Operating level	10 seconds
	5 kHz	Operating level	10 seconds
	2.5 kHz	Operating level	10 seconds
	1 kHz	Operating level	10 seconds
	500 Hz	Operating level	10 seconds
	250 Hz	Operating level	10 seconds
	100 Hz	Operating level	10 seconds
	50 Hz	Operating level	10 seconds
	30 Hz	Operating level	10 seconds

ALIGNMENT			
IN/S	FREQUENCY	REPRODUCER OUTPUT VOLTAGE LEVEL	DURATION
7.5	700 Hz	10 dB below operating level	15 seconds
	15 kHz	10 dB below operating level	30 seconds
	12 kHz	10 dB below operating level	10 seconds
	10 kHz	10 dB below operating level	10 seconds
	7.5 kHz	10 dB below operating level	10 seconds
	5 kHz	10 dB below operating level	10 seconds
	2.5 kHz	10 dB below operating level	10 seconds
	1 kHz	10 dB below operating level	10 seconds
	500 Hz	10 dB below operating level	10 seconds
	250 Hz	10 dB below operating level	10 seconds
	100 Hz	10 dB below operating level	10 seconds
	50 Hz	10 dB below operating level	10 seconds
	700 Hz	Operating level[6]	15 seconds
FLUTTER			
3.75		2 dB above operating level	30 minutes
7.5		2 dB above operating level	15 minutes
15		2 dB above operating level	7.5 minutes
LEVEL			
7.5		Operating level[6]	10 minutes
15		Operating level[6]	5 minutes

NOTES

1. Has additional 1-min, 3-kHz signal at operating level as first tone.

2. One-inch tapes, except for 4690041-01, have two times the duration shown, and two-inch tapes have four times the duration shown.

3. Tape 4690007-02 is identical to 4690007-01, except is recorded on back-treated tape.

4. Tape 4690041-01 has the following program and levels at 7½ in/s: durations shown are at 240 in/s:

   a. 700 Hz, operating level, 12.5 seconds.
   b. 700 Hz, 10 dB below operating level, 7.5 seconds.
   c. 10 kHz, 10 dB below operating level, 12.5 seconds.
   d. 5 kHz, 10 dB below operating level, 5 seconds.
   e. 2.5 kHz, 10 dB below operating level, 5 seconds.
   f. 50 Hz, 10 dB below operating level, 5 seconds.

5. Time constants for 30 in/s are per AES proposal, volume 19, page 68, Jan. 1971.

6. OPERATING LEVEL, at 500 and 700 Hz, corresponds to a tape flux per unit width of 185 nanowebers/meter (Refer to. McKnight, John G., "Flux and Flux-Frequency Measurements and Standardizatior in Magnetic Recording," Journal of the SMPTE, Vol. 78, June 1969, pp 457-472.)

7. All tapes are supplied in boxes, on the following size and type reels:
   - o ¼-in.: 7-in., plastic, 4 in. hub
   - o Catalog No. 6878. 8-in., NAB
   - o ½-in.: 8-in., NAB
   - o 1-in.: 8-in., NAB
   - o 2-in.. 8-in., Precision (10.5-in. precision for 30 in/s)

8. Accompanying each tape is a technical brochure describing the use and care of the tape.

9. Special Test Tapes: Contact your nearest Ampex representative for price and delivery information.

10. Ampex Corporation reserves the right to change prices without notice and without obligation. These prices supersede all previous pri stated or implied.

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MM-1000 Series Recorder/Reproducer

SPECIFICATIONS

AMPEX

The Sound Revolution has brought with it sweeping changes in approach. Mastering now calls for much greater operational flexibility in recording equipment. And the MM-1000, a multichannel recorder/reproducer from Ampex, was conceived to lead the revolution.

The MM-1000 is a professional audio tape recorder designed to handle one-inch or two-inch tape with remarkable reliability. It is basically a 16-channel machine, available in both 8-channel and 24-channel configurations as well. Machines can be expanded or reduced by eight-channel increments to any of the three configurations.

SPECIFICATIONS

Tape Speeds (Dual):

7.5 and 15 ips or 15 and 30 ips

Number of Channels:

8-, 16- or 24-channels

Signal-to-Noise Ratio:

7.5/15 ips or 15/30 ips;

8- and 16-channel, 60 dB min.

24-channel, 55 dB min.

Peak record level to unweighted noise (30 Hz to 18 kHz). Includes bias, erase, and playback amplifier noise using Ampex 404 Series tape or equivalent.

Frequency Response (Overall):

30 ips: ±2 dB, 50 Hz to 20 kHz

15 ips: ±2 dB, 30 Hz to 18 kHz

7.5 ips: ±2 dB, 40 Hz to 15 kHz

Erasure (Selective erasure on each channel):

7.5/15 ips and 15/30 ips:

8- and 16-channel, 70 dB

24-channel, 50 dB

Flutter:

15 and 30 ips below 0.08% rms
7.5 ips below 0.1% rms
percentage of total flutter is measured by the methods of the ASA 257.1-1-1954, in a band 0.52200 Hz, while reproducing an Ampex flutter test tape (flutter on test tape less than 0.03%)

Third Harmonic Distortion:

7.5/15 ips and 15/30 ips: below 1.1% at normal operating level.

Crosstalk:

50 dB minimum, 8- and 16-channel at 500 Hz.

45 dB minimum, 24-channel at 500 Hz.

Playback Output:

+4 dBm into 600 ohms, restrappable for +8 dBm output, balanced or unbalanced. Maximum +28 dBm before clipping.

Record Input:

100K unbalanced bridging with dummy plug supplied or 20K balanced bridging with plug-in transformer supplied with each electronics. −17 dBm to produce recommended operating level.

Electronic Adjustments:

Accessible from front: equalization, reproduce level, record level, record calibration, reproduce calibration, bias adjustment, bias calibration, erase adjust, SEL-SYNC®* system level and bias trap adjustments.

Heads:

8-track head stacks have adjustable azimuth, 16- and 24-track head stacks are fixed azimuth.

Indicators:

1. Illuminated transport controls.
2. "Red" record, "Yellow" non-record, "Green" SEL-SYNC system.

(Specifications continued on overleaf.)

*SEL-SYNC is an Ampex trade name.

Timing Accuracy:
±0.1% (±1.8 seconds in 30 minute record time) for a reel of tape recorded, rewound and played back on the same unit; ±0.2% from unit to unit.

Tape Position Index:
Reads hours, minutes, and seconds with repeat accuracy of ±0.1% (15 ips only).

Timing Reference:
If capstan is driven from ac motor, ac line is standard. If dc capstan motor is used, the reference is an external frequency standard, or an internal crystal accurate to 0.01%. Variable frequency accessory is available.

Tape Width:
One-inch and two-inch wide NAB reels. Ampex Series 434 (1.5 mil) or 444 (1.0 mil) low-noise mastering tape recommended.

Equalization:
All standard models supplied with NAB or IEC (CCIR) equalization.

Rewind Time:
1.4 minutes to rewind 10½-inch reel using 2-inch, 1.5-mil tape.

Start Time:
Tape at full speed in less than 0.5 second.

Power Requirements:
117 volts, 50 or 60 Hz.

MM-1000-8	0.65 KVA MAX.
MM-1000-16	0.85 KVA MAX.
MM-1000-24	1.1 KVA MAX.

Dimensions:
Height: 65.0 inches
Width: 42.3 inches
Depth: 27.5 inches

Sidecar rack for MM-1000-24:
Height: 65.0 inches
Width: 25.0 inches
Depth: 25.0 inches

Weight:
MM-1000-8 approximately 500 lb
MM-1000-16 approximately 630 lb
MM-1000-24 approximately 750 lb

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